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Vol. XIV, Part VI December, 1944

THE
INDIAN JOURNAL
OF
AGRICULTURAL SCIENCE

Issued under the authority
of
The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 3 or 5s.

Published by the Manager of Publications, Delhi
Printed by the Manager, Government of India Press, Calcutta
1945

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The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

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ORIGINAL ARTICLES

PHOTO-HYDROLYSIS OF STARCH

By M. R. Madhok and Fazal-Uddin, Bacteriological Research Laboratories, Punjab Agricultural College, Lyallpur

(Received for publication on 17 June 1944)

Hydrolysis of starch by the action of enzymes and acids is a well-known phenomenon. Biedermann in his series of publications [1919-1924] reported that certain neutral salts such as potassium phosphate, sodium chloride, etc. could also hydrolyse starch. He further found that a mixture of sodium chloride, potassium phosphate and glycine was capable of hydrolysing a 1 per cent solution of starch in two hours.

A number of workers like Bachrach [1921], Bokorny [1921], Teschendorf [1921], Rothlin [1922] could not, however, confirm his results and attributed the observed hydrolysis to either the contamination of starch with amylase or to bacterial action. Other workers, like Haehn [1924] and Iljin [1924], confirmed Beidermann's findings.

During our investigations on the losses of nitrogen from sodium nitrite in the presence of starch, it was incidentally noted that starch disappeared completely from flasks which were exposed to the sun for sometime. On the other hand, flasks kept in the dark continued to give a positive reaction for starch. Besides a slight reduction and oxidation, denitrification of sodium nitrite was also observed in the presence of light.

(A). So far as the transformation of starch is concerned the foregoing experiment was only of a qualitative nature. That starch disappeared in the presence of sunlight was quite obvious, but it remained to be seen whether starch in the unexposed flasks had undergone any transformation. Another experiment was therefore conducted with 0·5 per cent starch solution. Determination of starch was made after five weeks duration by the starch iodide gravimetric method.

The results given in Table I showed that starch is not hydrolysed in the dark even in the presence of sodium nitrite and the change is entirely a photo-chemical one. The sterility of the solution in the flasks was tested before analysis.

Table I

Starch in gm. per 100 c.c. solution

Exposed	Un-exposed	
	With nitrite	Without nitrite
Nil	0·48	0·51
Nil	0·50	0·50

A number of experiments on various aspects of the subject were then conducted. The technique followed and the material used throughout, except where otherwise mentioned, were as follows :

Soluble starch (May and Baker) was used in all the experiments. The solution was exposed in Pyrex glass rimless culture tubes measuring 6 in.×0·5 in. Paper was always tied over the plugs to protect them from dust. Ten c.c. of 0·1 per cent starch solution were put in the tubes. Sterilization was done in the autoclave at 15 lb. pressure for half an hour. Sodium nitrite was used in 0·2 per cent concentration as a catalyst and its solution was sterilized separately and added aseptically when required.

(B). Since nitrite in the presence of starch undergoes both reduction and oxidation, experiments were conducted to determine the extent to which the three ions, viz. NH_4, NO_3 and NO_2 catalyse the reaction. For this purpose, solutions of sodium nitrite, sodium nitrate and ammonium sulphate were prepared on equal nitrogen basis, sterilized and used as catalysts.

The results obtained showed that in the presence of sodium nitrite starch disappeared in about a week's time, while in the presence of sodium nitrate it took over four weeks. In the presence of ammonium sulphate a positive reaction for starch was obtained even after a lapse of many weeks.

It is likely that the destruction of starch in the case of sodium nitrate may be due partly or entirely to the presence of NO_2 ions produced as a result of the photo-reduction of nitrate, but it is not clear from the results of the above experiment as to how far this is due to the presence of one or the other ion (NO_2 or NO_3) or to the combined action of both. However, even if NO_3 ions catalyse this reaction, their effect seems to be much slower.

(C). An experiment was conducted to ascertain if dextrin can be hydrolysed in the presence of sodium nitrite. For this purpose a 0·2 per cent solution of dextrin was used. The results obtained showed that dextrin completely disappeared in 10 days in the exposed tubes treated with sodium nitrite while the unexposed tubes continued to give a positive test up to the end of six weeks, when the experiment terminated.

Qualitative tests carried out to detect the disappearance of starch in the preliminary experiments often gave a reddish brown colouration with iodine solution in the exposed tubes indicating the presence of dextrin in the solution. Other tests, the alcohol and basic lead acetate tests, also showed its presence when 0·5 per cent starch solution was tested after the disappearance of starch. The solution when free from starch and dextrin (as shown by the iodine test) was also found to reduce Fehling's solution showing thereby the presence of reducing sugars. The reducing power of a 0·2 per cent starch solution was found to be equivalent to 0·08 per cent solution of glucose.

As the starch is first converted into dextrin and then into reducing sugars, evidently this is a case of hydrolysis. In order to study the effect of various factors on this reaction, the following experiments were undertaken :

REACTION OF THE SOLUTION

In order to determine the effect of reaction on the rate of hydrolysis of starch, the experiment was conducted at a *p*H of 5·2 and 8·6. The rate of hydrolysis was found to be the same at both the *p*H values. The *p*H of the tubes was again determined at the end of the experiment and was found to be practically the same as at the beginning.

The *p*H was adjusted by the addition of $N/10$ HCl or $N/10$ NaOH and both these reagents were found to have no action on the hydrolysis of starch in the absence of sodium nitrite.

CONCENTRATION OF THE CATALYST

Four concentrations, viz. 1·0, 0·2, 0·04 and 0·008 per cent of sodium nitrite were tried. The rate of hydrolysis of starch was found to be practically the same in all concentrations from 0·04 to 1·0 per cent. With a 0·008 per cent concentration of the nitrite it was, however, found to be definitely lower.

RATE OF HYDROLYSIS OF DIFFERENT STARCHES

An experiment was conducted to compare the rate of hydrolysis of some different starches. The results given in Table II show that the rate of hydrolysis varies in different cases. Potato and soluble starch are more readily hydrolysed as compared to other starches from wheat, maize, rice, etc.

TABLE II

Starch	After 7 days		After 11 days		After 28 days		After 48 days	
	Starch	Dextrin	Starch	Dextrin	Starch	Dextrin	Starch	Dextrin
Buck wheat	+		trace	+	—	—	—	—
Sol. starch	—	+	—	trace	—	—	—	—
Potato	—	+	—	trace	—	—	—	—
Wheat	+		+		trace	+	—	—
Maize	+		+		trace	+	—	—
Rice	+		+		trace	+	—	—

WAVE LENGTH OF LIGHT

The experiment was conducted in usual way in culture tubes, which were kept immersed in clear water or coloured violet or red and then exposed to the sun. As expected the shorter waves were found to be more effective than the longer waves.

INFLUENCE OF DIFFERENT COMPOUNDS

(*a*) In order to determine the effect of other sodium salts on the hydrolysis of starch, a series of trials were conducted as usual with sodium acetate, borate, carbonate, phosphate, tartarate and chloride. The concentration of the starch solution and of the catalyst used in each case was 0·1 and 1·0 per cent respectively. The experiment lasted for two months. The results were negative in every case, i.e. disappearance of starch was not noted in any case.

(*b*) Other substances like mercuric oxide, bismuth oxide, zinc oxide, reduced nickel and animal charcoal were also tried as catalysts. The oxides were washed free of any traces of NO_2 before use. A 0·1 gm. of the catalyst was added to each tube. After sterilization the cotton wool plugs were replaced by sterilized tight-fitting corks. This was considered necessary in order to keep off atmospheric ammonia which gets oxidized to nitrite in the presence of oxidizing photo-catalysts. The experiment lasted for four weeks. It was found that zinc oxide acted catalytically on the hydrolysis of starch. The rate of hydrolysis appeared to be the same as with sodium nitrite. Mercuric oxide acted positively but the action was rather weak.

(*c*) Another experiment was conducted to verify the claims of Biedermann [1919-1924] that a mixture of glycine, potassium phosphate and sodium chloride hydrolysed starch in two hours. As the original article by Biedermann was not available, the trial was conducted as follows :

A 0·1 per cent starch solution was prepared with 0·2 per cent each of potassium phosphate, sodium chloride and glycine.

It was tubed in 10 c.c. portions and sterilized. Some tubes were exposed to the sun and the others were kept in the dark. Occasional tests with iodine solution up to a period of six weeks did not show the disappearance of starch.

SUMMARY

1. Starch undergoes hydrolysis under the action of light in the presence of catalysts.

2. Shorter waves of light are more active in their effect than the longer waves.

3. Sodium nitrite, zinc oxide and mercuric oxide act as catalysts for the hydrolysis of starch.

4. The rate of hydrolysis varies with different starches.

5. The rate of hydrolysis is unaffected between the *p*H range 5·2-8·6.

6. A mixture of potassium phosphate, sodium chloride and glycine did not catalyse the hydrolysis of starch as observed by Biedermann.

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STUDIES ON THE ROOT-ROT DISEASES OF COTTON IN THE PUNJAB

XIII. LEAF TEMPERATURES OF HEALTHY AND ROOT-ROT AFFECTED PLANTS

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(Received for publication on 8 May 1944)

Root-rot disease of cotton is the most serious disease of this crop in the Punjab and causes heavy damage to the crop every year [Vasudeva, 1935]. In a freshly wilted plant excepting a few roots which hold the plant in position, most of the other roots are decayed and bark broken down into shreds. The food supply of the plants is thus cut off and the plants are killed out right within a very short period. The disease actually starts much earlier, and the above-ground manifestation of the disease in the form of wilting is a very late symptom.

In the course of some field experiments in which the cotton plants attacked by root-rot were under study it was observed that the leaves of the affected plants have decidedly a higher temperature. The experimental data are recorded in this paper and it may later on be possible to use leaf temperature as an index for the identification of plants affected by root-rot disease. The experiments though have no direct bearing on the problem are nevertheless cognate to the subject and are included in this series.

EXPERIMENTAL

The temperature of the leaves was recorded by the thermo-electric method. The apparatus employed consisted of constantan wire, copper wire, a unipivot galvanometer, a spring key and centigrade thermometers. The ends of the constantan wire were soldered with the ends of the two copper wires; the absorption coefficient of these wires being nil. The free ends of the copper wires were connected to the galvanometer and the spring key respectively. The key and the galvanometer were connected by a similar piece of copper wire. All the wires were carefully insulated with rubber valve-tubing. A galvanometer sensitive enough to indicate at least 0·0025 microamperes was used.

Of the two thermo junctions one was placed in a Dewar's flask containing cold water along with a thermometer and served as the 'cold juction'. In order to guard against the sudden fluctuations in air temperature, the Dewar's flask was kept in a wooden box containing sawdust. The temperature of the water in the flask was kept constant at about 10°C. In measuring the temperature, the leaf was folded upwards in such a way that two portions of the upper surface were brought firmly together over the free juction by means of a pair of tongs, the tips of which had been previously covered with pieces of cork. The circuit was then completed by inserting the key. The deflection caused by the difference of temperature of the two junctions was recorded. The internal temperature of the leaves was determined by inserting the free junction in the tissue of the mid-rib. The corresponding temperature of air was recorded by holding the free junction in air and necessary precautions to protect it from the direct rays of the sun were taken. Two cotton plants of variety *Gossypium indicum* (15 Mollisoni) standing in the same field, of the same age and as far as possible of the same size were selected early in the morning every day: One which just showed the first apparent signs of wilting, i.e. slight drooping of top-most leaf, and the other which appeared perfectly normal and healthy. The leaf temperature was measured four times during the day, i.e. at 6·30 a.m., 9 a.m., 12 noon and 5 p.m. Temperatures of six leaves were determined on each plant at one time; the readings for the temperature determinations of healthy leaves alternating with those of the diseased ones. Corresponding temperature of air at that particular time was also recorded. Leaves which faced the sun at right angles were always selected so that the results could be strictly comparable.

The leaf temperatures were recorded during a number of days on different pairs of healthy and diseased plants during July and August. Determinations of the leaf surface and inner tissue temperatures were made simultaneously. Data for a single pair of plants are recorded in Table I.

TABLE I

Leaf temperatures of a healthy and a diseased cotton plant at different times of the day

Time	Temperature of air °C.	Temperature of old junction °C.	No. of deflections of the galvanometer			Calculated temperature			Healthy or diseased	Value of *t*	
			Air	Upper surface	Inner tissue	Air	Upper surface	Inner tissue		Upper surface	Inner tissue
6.30 a.m.	29·4	23·4	21	25	25	29·4	30·52	30·52	H	4·17	4·10
				27	27		31·09	31·09	D		
	29·6	23·4	27	25	24	29·6	29·12	28·89	H		
				28	28		29·86	29·80	D		
	29·8	23·4	26	27	27	29·8	30·04	30·04	H		
				30	30		30·73	30·73	D		
	30·0	23·4	28	28	28	30·0	30·00	30·00	H		
				30	30		30·47	30·47	D		
	30·2	23·4	28	28	28	30·2	30·20	30·20	H		
				35	35		31·90	31·90	D		
	30·4	23·4	29	29	27	30·4	30·40	29·92	H		
				36	35		32·09	31·85	D		

TABLE I—*contd.*

Time	Temperature of air °C.	Temperature of old junction °C.	No. of deflections of the galvanometer			Calculated temperature			Healthy or diseased	Value of *t*	
			Air	Upper surface	Inner tissue	Air	Upper surface	Inner tissue		Upper surface	Inner tissue
9.0 a.m.	34·0	24·8	35	38	31	34·0	34·79	32·95	H	7·85	7·55
				46	43		36·89	36·10	D		
	34·0	24·8	35	40	33	34·0	35·31	33·50	H		
				47	43		37·15	36·10	D		
	34·0	24·8	35	38	34	34·0	34·79	33·73	H		
				48	43		37·41	36·10	D		
	34·2	24·8	35	37	34	34·2	34·73	33·93	H		
				50	40		38·32	35·54	D		
	34·4	24·8	36	39	37	34·4	35·20	36·66	H		
				54	44		39·20	36·53	D		
	34·4	24·8	38	42	38	34·4	35·41	34·40	H		
				51	43		37·68	35·66	D		
12.0 Noon	38·4	25·4	44	49	42	38·4	39·87	37·81	H	15·73	4·63
				56	47		41·94	39·28	D		
	38·4	25·4	46	47	43	38·4	38·68	37·55	H		
				55	46		40·94	38·40	D		
	38·6	25·4	45	48	43	38·6	39·48	38·01	H		
				60	52		43·00	40·65	D		
	38·6	25·4	43	49	44	38·6	40·44	38·95	H		
				59	53		43·51	41·67	D		
	38·8	25·4	44	49	43	38·8	40·32	38·50	H		
				59	51		43·36	40·93	D		
	38·8	25·4	44	48	44	38·8	40·21	38·50	H		
				57	45		42·76	39·10	D		
5.0 p.m.	38·4	28·8	44	46	43	38·4	38·83	38·18	H	12·38	4·78
				55	46		40·80	38·83	D		
	38·4	28·8	43	44	41	38·4	38·62	37·95	H		
				54	48		40·85	39·51	D		
	38·4	28·8	41	38	34	38·4	37·69	36·76	H		
				48	40		40·04	38·16	D		
	38·4	28·8	42	33	30	38·4	36·34	35·65	H		
				44	40		38·86	37·94	D		
	38·4	28·8	39	36	32	38·4	37·66	36·67	H		
				47	37		40·37	37·90	D		
	38·4	28·8	39	39	36	38·4	38·40	37·66	H		
				45	38		39·88	38·15	D		

It is observed that diseased plants remain considerably warmer as compared with the healthy ones. To show the statistical significance of the differences in temperature recorded, a function *t* was calculated from the data as described by Fisher [1924]. For a series of six observations the value of *t* 2·57 is just on the margin of significance. (The usual 20 : 1 standard being adopted). The temperature differences both of upper surface and inner tissue of the diseased and healthy leaves are found to be significant. The inner tissue temperature shows a constantly lower value than the surface temperature and this holds good in the healthy as well as in the diseased plants. The value of *t* for the comparisons as shown in Table I is extremely high. This represents enormously great probability that the temperature of the leaves of a diseased plant is higher than that of the leaves of a healthy plant. The same type of experiments were repeated using different pairs of plants with similar results.

All the comparisons shown above are clearly significant and are in accordance with the observations of Ezekiel and Taubenhaus [1932] for *Phymatotrichum* root-rot and with Luthra and Chima [1937] who brought about wilting of the cotton plants by withholding the water supply.

Preliminary experiments conducted to determine the rate of transpiration of healthy and root-rot affected cotton plants showed that the rate of transpiration is considerably higher in healthy plants. The increase in temperature of root-rot affected plants is probably due to the defective root absorption as a result of which the moisture supply of the leaves is curtailed and the heat incident on the leaves is not dissipated resulting in the warming up of the leaves. On the other hand, in healthy plants the transpiration is fairly active and consequently the leaves remain comparatively cool.

The observations recorded were made during the course of the investigation of root-rot disease of cotton in the Punjab financed by the Indian Central Cotton Committee to whom my thanks are due.

Thanks are also due to Mr Inder Singh Chima of the Botanical Section, Agricultural College, Lyallpur, for his assistance.

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STUDIES ON THE ROOT-ROT OF COTTON IN SIND

II. RELATION OF ROOT-ROT OF COTTON WITH ROOT-ROT OF OTHER CROPS

By N. Prasad, Assistant Mycologist, Department of Agriculture, Sind, Sakrand

(Received for publication on 28 February 1944)

It has been observed that in addition to cotton, certain other crops suffer every year from root-rot. The crops most commonly attacked are castor (*Ricinus communis* L.), sesamum (*Sesamum orientale* L.), sunn-hemp (*Crotalaria juncea* Coso.), and *guar* (*Cyamopsis psoraloides* D. C.). Of all these sesamum and *guar* are the most affected.

The symptoms in all cases are similar to that of root-rot of cotton. The affected plants wilt suddenly. On pulling out the plants, it is seen that most of the lateral roots become fibrous, a yellow liquid oozes out on squeezing them and the roots ultimately rot. All the above-mentioned crops are cultivated during the summer months and root-rot is active from the beginning of June right up to the end of October.

Vasudeva [1935] also reports that root-rot affects several crops in the Punjab and that the causal organism is probably the same in all cases, i.e. *Rhizoctonia bataticola* (Taub.) (Butl.). In Sind the root-rot of cotton is caused by two fungi *Rhizoctonia bataticola* (Taub.) Butl. and *Fusarium coeruleum* (Lib.) Sacc. Both cause the disease either singly or together. This investigation was undertaken to find out whether the cause of the disease in different crops mentioned above is the same in Sind.

MATERIAL AND METHODS

Rot-affected roots of castor, sunn-hemp, *til* (sesame) and *guar* were collected at different times from different places. Isolations from them were made at regular intervals. For isolation of the causal organisms (1) the mercuric chloride-sterile water, and (2) silver nitrate-sodium chloride methods were used. Numerous types of fungi were obtained in isolations from each crop.

Fungi like *Pennicilium* were not taken into consideration, and others were grouped together, to avoid handling a large number of isolates. The basis of grouping them together was the same as in the case of cotton, i.e. discolouration of the medium, presence or absence of aerial mycelium and spore-bearing structures.

TABLE I

Types of fungi isolated from different crops

Type No.	Aerial mycelium	Discolouration of medium	Spore bearing structures
1	Whitish fluffy	Light brown	None
2	Pinkish	Pink	None
3	None	None	Abundant sclerotia
4	Scanty whitish	Dark brown	Abundant sclerotia
5	White	Dark brown	Abundant sclerotia
6	Dirty white	Black	Abundant sclerotia
7	Buff	Brown	Pinnotes present

It was found that isolates No. 1 and No. 3 appeared most frequently and that they were *Fusarium* and *Rhizoctonia*, respectively. Both of them were selected for carrying out further infection experiments.

INFECTION TESTS

Experiment I

Inoculum was prepared in the usual way by growing cultures of *Rhizoctonia* isolated from each crop on soil and wheat flour. The seeds of various crops were sown in pots containing sterilized soil, and in between the two layers of inoculum, 12 seeds were sown in each pot.

The seedlings emerged from the soil 10 days after sowing. Twenty-five days later wilting was observed. The experiment terminated on 20 June 1941 and the final figures are given in Table II.

TABLE II

Germination and rotting with isolates of Rhizoctonia *from different crops*

Type of isolate	Crops	Total No. of seedlings	No. of seedlings which rotted	Germination percentage	Rotting percentage
Isolate from cotton	Cotton	31	13	64·5	41·9
	Castor	33	18	68·7	54·5
	Sunn-hemp	40	21	83·3	52·5
	Guar	43	26	79·5	60·4
	Til	45	27	93·7	60·0
Isolate from castor	Cotton	29	16	60·4	55·1
	Sunn-hemp	27	12	56·2	44·4
	Guar	37	10	77·0	27·0
	Castor	35	19	72·9	54·2
	Til	39	16	81·2	41·0
Isolate from sunn-hemp	Cotton	32	17	66·6	53·1
	Castor	41	22	85·4	53·6
	Sunn-hemp	36	15	75·0	41·6
	Guar	35	21	72·9	60·0
	Til	43	31	79·5	72·0
Isolate from *guar*	Cotton	29	16	60·4	55·1
	Castor	29	13	60·4	44·8
	Sunn-hemp	31	17	64·5	54·8
	Guar	33	21	68·7	63·6
	Til	37	15	77·0	40·5
Isolate from *til*	Cotton	34	13	70·8	38·2
	Castor	37	21	77·0	56·7
	Sunn-hemp	32	17	66·6	53·1
	Guar	35	16	72·9	45·7
	Til	42	22	87·5	52·3

Isolations were made from one of each series and the cultures so obtained were compared with cultures with which they were infected. Practically in all the cases they were found to be the same. Thus it is quite clear from Table II that rotting in case of all the crops is caused by *Rhizoctonia* and the fungus isolated from the rotted roots is pathologically the same. The results obtained in this experiment were confirmed.

Experiment II

Similar experiment was carried out with *Fusarium* isolated from the rotted roots of the above-mentioned crops. Inoculum was prepared in the usual way and pots were infected as described above. Twelve seeds were sown in each pot.

The seeds germinated 10 days after sowing and first wilting appeared 29 days after germination. This experiment terminated on 25 September 1941. The results of the experiment are given in Table III.

TABLE III

Germination and rotting percentage with isolates of Fusarium *from the affected roots of various crops*

Type of isolate	Crops	Total No. of seedlings	No. of seedlings which eventually rotted	Germination percentage	Rotting percentage
Isolate from cotton .	Cotton . . .	25	7	52·0	28·0
	Castor . . .	23	8	47·9	34·7
	Sunn-hemp . .	27	6	56·2	33·3
	Guar . . .	30	15	62·5	50·0
	Til	45	25	93·7	55·2
Isolate from castor .	Cotton . . .	23	6	47·9	26·0
	Castor . . .	29	11	60·4	37·9
	Sunn-hemp . .	35	13	72·9	37·1
	Guar . . .	32	12	66·6	37·5
	Til	46	20	95·8	43·4
Isolate from sunn-hemp	Cotton . . .	24	8	50·0	33·3
	Castor . . .	17	5	35·4	29·4
	Sunn-hemp . .	40	15	83·3	37·5
	Guar . . .	30	15	62·5	50·0
	Til	40	15	83·3	37·5
Isolate from *guar* .	Cotton . . .	20	5	41·6	25·0
	Castor . . .	26	6	54·1	23·0
	Sunn-hemp . .	30	10	62·5	33·3
	Guar . . .	26	6	54·1	23·0
	Til	39	25	81·2	64·1
Isolate from *til* . .	Cotton . . .	19	4	39·5	21·0
	Castor . . .	29	9	60·6	31·0
	Sunn-hemp . .	20	6	41·6	30·0
	Guar . . .	36	11	75·0	30·5
	Til	43	16	89·5	37·2

Isolations were made from each one of the series and the cultures so obtained were compared with the cultures with which they were infected. In all cases they were found to be the same. The results obtained in the above experiment show that *Fusarium* isolated from the above-mentioned crops is also capable of causing root-rot in case of all the crops. This shows that *Fusaria* isolated from different crops are pathologically similar.

MORPHOLOGY OF THE ROOT-ROTTING FUNGI

Various types of *Rhizoctonia* isolated from different crops were grown along with a known culture of *Rhizoctonia bataticola* (Taub.) Butl. obtained from the Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi, on potato dextrose agar and oatmeal agar. Measurements of sclerotia and breadth of mycelium were taken. In all the cases, measurements of the breadth of mycelium and sclerotia were found to be the same. Diameters of sclerotia were found to range between 60-120μ.

These isolates never formed pycnidia although they were grown in several other media and media with varying *p*H. Morphologically these isolates resembled *Rhizoctonia bataticola* (Taub.) Butl. in all respects and therefore they have been given that name.

The *Fusaria* isolated from the affected roots of the above-mentioned crops were grown on Wollenweber's [1925] standard media for *Fusarium*.

Colours of the mycelium were noted after 14 days growth. Measurements of 200 spores in each case were taken on 2 per cent potato dextrose agar. Aerial mycelium was present in all cases. Bluish green sporodochia were also present while sclerotia were absent. Only in case of isolate from *til*, there was a concentration of spores on the surface of the medium, resembling a pionnote. Terminal chlamydospores were produced in abundance by each isolate on practically every medium while the inter-calary chlamydospores were mostly produced on potato cylinder or steamed rice. The length and breadth of micro- and macro-conidia were found to be the same in all cases and were found to vary in the following range :

0—Septate	(6—15)	(3—6)μ
1—Septate	(9—20)	(3—6)μ
2—Septate	(13—33)	(3—7)μ
3—Septate	(25—40)	(3—7)μ

DISCUSSION

The isolations carried out in this study have shown that root-rot in cotton and certain other crops is caused by a species of *Rhizoctonia* and *Fusarium*. It has already been reported by Prasad [1944] that *Fusarium coeruleum* (Lib.) Sacc. is associated with root-rot of cotton in Sind. On careful comparison of the cultures of all the *Fusaria* isolated from the above-mentioned crops, it has been definitely established that they belong to the species of *Fusarium coeruleum* (Lib.) Sacc. A similar study of *Rhizoctonia* sp. isolated from the affected roots has indicated that it belongs to *Rhizoctonia bataticola* (Taub.) Butl.

SUMMARY

Isolations carried out from the rot-affected roots of cotton, castor, sunn-hemp, *guar* and *til* yielded cultures of *Rhizoctonia* and *Fusarium*. Both of these fungi were found to be parasitic and further isolates of each one of them from different crops were found to be morphologically and pathologically similar. They were identified as *Rhizoctonia bataticola* (Taub.) Butl. and *Fusarium coeruleum* (Lib.) Sacc.

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RHIZOCTONIA ROOT-ROT OF *PAN* (*PIPER BETLE*) IN RELATION TO MANURING

By S. CHOWDHURY, Plant Pathological Laboratory, Sylhet, Assam

(Received for publication on 17 June 1944)

ROOT-ROT of *pan* (*Piper betle* Linn.) due to *Rhizoctonia solani* Kuhn is very serious in Assam and causes heavy damage to the crop wherever it occurs. Mustard oilcake is the only manure used for *pan*. It is ground very fine, spread along the ridges and then covered with a very thin dressing of soil. During the first year of planting oilcake is applied at the rate of 12 md. per acre and during the subsequent years it is applied at the rate of 36 md. per acre. Manuring is done during the rains, once a month commencing from May and ending in September or October. Equal quantities of manures are applied at each application. In all, usually five or six applications are made during a year.

Oilcake is an organic manure and it was presumed that it might serve as a nutrient medium for the growth of *Rhizoctonia* and might influence the root-rot disease of *pan* and that the virulence of the disease might be checked or minimized by replacing oilcakes by fertilizers. Had this been possible it might have been possible to control the disease to a certain extent by this indirect method.

In order to test the truth of this assumption and the possibility of checking completely or partly the disease by manuring the plants with fertilizers an experiment was carried out. The results of this experiment are recorded in this paper.

MATERIALS AND METHODS

The experiment was laid out in a *boroj* land where all the plants have died of *Rhizoctonia* root-rot. The land was given an additional dose of infective material by incorporating with the soil cultures of *Rhizoctonia solani* Kuhn grown on sterilized paddy straw. The entire plot was divided into six blocks and each block into five plots of equal size. The randomized block system of layout was followed. Each plot was 45 ft. × 12 ft. There were 30 rows in each plot and 10 *pan* setts were planted on each row. Planting was done on 15 September 1940 and only healthy setts were planted.

The first manuring was done during the first week of May, 1941 and the subsequent manurings during the months June, July, August, September and October, 1941.

During the second year manuring was commenced in April and ended in September, 1942. Six applications were made, one application in each of the months April, May, June, July, August and September.

In every case the manuring was done the same day and at the same time. The method of application was also the same. The oilcake was ground very fine, then spread along the ridges and afterwards covered with a thin layer of fine earth. The fertilizers, on the other hand, were mixed with an equal quantity of fine earth, thoroughly mixed together and then applied along the ridges just like oilcake and then covered with a thin layer of soil.

The treatments were as follows :

A. *Mustard oilcake.* Applied at the rate of 984 lb. per acre during the first year, 1941, and at the rate of 2952 lb. during the second year, 1942. Samples of the oilcake applied were analysed and found to contain on an average 5·1 per cent nitrogen, 3·13 per cent phosphoric acid and 1·35 per cent of potash.

B. *Sodium nitrate.* Applied at the rate of 321 lb. per acre during the first year, 1941, and at the rate of 963 lb. during the second year, 1942. The samples were found to contain on an average 15·6 per cent of nitrogen.

C. *Ammonium sulphate.* Applied at the rate of 242 lb. per acre during the first year, 1941, and at the rate of 726 lb. per acre during the second year, 1942. The samples were found to contain on an average 21·0 per cent nitrogen.

D. *Mixture of sodium nitrate, superphosphate and potassium sulphate.* A mixture containing 321 lb. of sodium nitrate, 200 lb. of superphosphate and 25 lb. of potassium sulphate was applied per acre during the first year, 1941, and a mixture containing 963 lb. of sodium nitrate, 600 lb. of superphosphate and 75 lb. of potassium sulphate during the second year, 1942. Superphosphate was found to contain 16 per cent of phosphoric acid and potassium sulphate 48 per cent of potash.

E. *Mixture of ammonium sulphate, superphosphate and potassium sulphate.* A mixture containing 242 lb. of ammonium sulphate, 200 lb. of superphosphate and 25 lb. of potassium sulphate was applied per acre during the first year, 1941 and a mixture containing 726 lb. of ammonium sulphate, 600 lb. of superphosphate and 75 lb. of potassium sulphate during the second year, 1942. The percentages of phosphoric acid and potash were the same in superphosphate and potassium sulphate respectively as in D.

EXPERIMENTAL RESULTS

After manuring the number of deaths occurring in each of the plots was noted and are recorded in Tables I and II for the years 1941 and 1942. The dead plants were collected and examined ; it was found that in all cases the deaths occurred due to the attack of the parasite *Rhizoctonia solani* Kuhn.

It will be observed from the data presented in Tables I and II that the percentage of death is practically the same for all the treatments, there being no significant difference. As regards the yield of leaves it will be noted that it is slightly more in the oilcake-treated plots during both the years than in the plots treated with the fertilizers.

As to the general growth of the plants due to manuring it was found that the effects of the artificials were earlier visible on the plants than oilcake but in the long run no difference could be noticed between the plants given different treatments; the height of the plants, the size and colour of the leaves and the general vigour of the plants were indistinguishable. But during the cold weather and early part of the dry season (November-April) it was found that the oilcake-treated plants were in a better state of health and thriftiness than those receiving the artificials. This is probably due to the fact that oilcake increases the organic matter and humus content of the soil and thus helps the conservation of moisture. Further, the plant food materials contained in oilcake become gradually and slowly available to the plants; thus its effects are more lasting than the effects of the artificials. Another distinct advantage of oilcake over artificials was also noticed; it was found that in a region of heavy rainfall like Assam the chances of the manure getting washed away by the heavy showers is more with respect to the artificials than with oilcake.

The same experiments were repeated during the years 1942 and 1943 and results exactly similar to those cited above were obtained.

TABLE I

Effect of manuring on the incidence of Rhizoctonia *root-rot of* pan (*1941*)

Treatments	Pounds of fertilizing ingredients applied per acre			Replication	Total number of setts planted	Number of deaths during the year	Percentage of death	Average percentage of death for the treatment	Yield of leaves	Average yield of leaves for the treatment
	N_2	P_2O_5	K_2O							
A	50·18	30·8	13·28	1	300	52	17·3	19·4	11,904	11,600
				2	300	62	20·6		11,424	
				3	300	56	18·6		11,712	
				4	300	72	21·0		10,944	
				5	300	49	16·3		12,048	
				6	300	59	19·6		11,568	
B	50·76			1	300	61	20·3	19·36	9,799	9,852·8
				2	300	52	17·3		10,168	
				3	300	70	23·3		9,200	
				4	300	52	17·3		10,024	
				5	300	54	18·0		10,086	
				6	300	60	20·3		9,840	
C	50·82			1	300	58	19·3	19·68	9,922	9,873·6
				2	300	62	20·6		9,758	
				3	300	50	16·6		10,250	
				4	300	69	23·0		9,471	
				5	300	56	18·6		10,004	
				6	300	60	20·0		9,837	
D	50·76	32·0	12·0	1	300	51	17·0	19·53	10,207	9,895·1
				2	300	59	19·6		9,881	
				3	300	48	16·0		10,323	
				4	300	69	23·0		9,476	
				5	300	57	19·0		9,963	
				6	300	68	22·6		9,521	
E	50·82	32·0	12·0	1	300	61	20·3	19·51	9,789	9,845·8
				2	300	52	17·3		10,187	
				3	300	47	15·6		10,376	
				4	300	69	23·0		9,482	
				5	300	53	17·6		10,032	
				6	300	70	23·3		9,210	

TABLE II

Effect of manuring on the incidence of Rhizoctonia *root-rot of* pan *(1942)*

Treatments	Pounds of fertilizing ingredients applied per acre			Replication	Total number of setts planted	Number of deaths during the year	Percentage of death	Average percentage of death for the treatment	Yield of leaves	Average yield of leaves for the treatment
	N_2	P_2O_5	K_2O							
A	150·55	92·4	39·85	1	248	39	15·7	15·08	15,049	14,749·5
				2	238	31	13·02		14,894	
				3	244	39	15·9		14,742	
				4	228	29	12·7		14,297	
				5	251	42	16·7		15,046	
				6	241	40	16·5		14,469	
B	152·28			1	239	28	11·7	15·26	14,769	14,335·2
				2	248	41	16·5		14,496	
				3	230	37	16·07		13,497	
				4	248	39	15·7		14,629	
				5	246	42	17·07		14,276	
				6	240	35	14·5		14,329	
C	152·46			1	242	41	16·9	15·31	14,069	14,366·0
				2	238	30	12·6		14,559	
				3	250	38	15·2		14,829	
				4	231	36	15·5		14,252	
				5	244	39	15·9		14,349	
				6	240	38	15·8		14,138	
D	152·28	96·0	36·0	1	249	47	18·8	15·85	14,139	14,314·3
				2	241	36	14·9		14,349	
				3	252	43	17·06		14,629	
				4	231	29	12·5		14,132	
				5	243	41	16·8		14,245	
				6	232	35	15·08		13,792	
E	152·46	96·0	36·0	1	239	41	17·1	15·80	13,858	14,364·8
				2	248	39	15·7		14,598	
				3	253	46	18·1		13,927	
				4	231	32	13·8		14,399	
				5	247	40	16·2		14,476	
				6	230	31	13·9		14,931	

CONCLUSIONS AND SUMMARY

As a result of the experiments conducted with different manures it was found that the percentage of death of *pan* plants due to the attack of *Rhizoctonia solani* Kuhn is not influenced by the nature of the fertilizing material. The percentage of death has been found practically the same in the plots receiving oilcake, sodium nitrate, ammonium sulphate singly or sodium nitrate or ammonium sulphate in combinations with superphosphate and potassium sulphate. The yield of leaves, however, has been found slightly more in the oilcake treated plots.

ACKNOWLEDGEMENTS

My thanks are due to Dr G. W. Padwick, Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi, for critically going through the manuscript.

A LEAF SPOT OF *CARICA PAPAYA* L. CAUSED BY A NEW SPECIES OF *PHYLLOSTICTA*

By S. CHOWDHURY, Plant Pathological Laboratory, Sylhet, Assam

(Received for publication on 29 June 1941)

(With Plate XII and one text-figure)

AT Haflong (Assam) and its vicinity in the North Cachar Hills *papaya* (*Carica papaya* L.) is grown extensively by the hill people. The plants are raised on the hill slopes and once established they receive practically no care.

In 1940, a very serious leaf spot due to a species of *Phyllosticta* was first noticed in these plantations. The disease has been observed ever since and causes considerable annual damage. It is as a rule prevalent in the months of September to January after which it is practically absent. The disease has not so far been observed in any other part of Assam.

SYMPTOMS OF THE DISEASE

The spots are restricted entirely to the leaves, and vary considerably in size; some are small and roundish, being a millimeter in length and a millimeter or three-fourths of a millimeter in breadth; others are irregular, oval or elongated having a size 3-15 mm. in length and 2-11 mm. in breadth. The spots are almost white in the centre and often bounded by a yellowish or brownish margin which gradually merges into the normal green of the leaf. The central portion of the spots is thin and papery and ultimately becomes brittle and falls out, giving a shot-hole appearance. In this portion are seen a number of minute dark brown to black pycnidia. The spots are usually isolated but may become confluent, forming big patches. Sometimes a large number of spots develop on the leaf, which then turns brown, dries up and is shed. Plate XII shows the symptoms of the disease.

MORPHOLOGY OF THE PARASITE ON THE HOST

Pycnidia. The pycnidia (Fig. 1, *a*) are formed on the dead portions of the leaf spots, on the upper surface. They are at first sub-epidermal but later become erumpent. They are globose to sub-globose, usually with distinct ostioles, dark brown to black and measure 80-115 × 60-95 μ.

In sections the pycnidial wall is thin below, consisting of one or two layers of dark coloured stroma, but is much thicker at the top; after the formation of the ostiole the thickened wall persists around the short neck. Next to the wall within are the narrow sporogenous layers of hyaline parenchyma cells bearing the conidiophores.

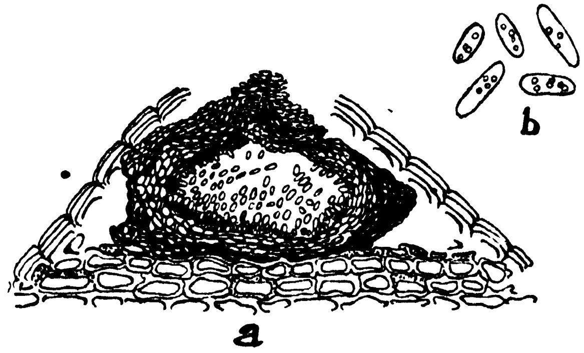


FIG. 1.—*a* : Section through a pycnidium ; *b* : Pycnospores

Pycnospores. The pycnospores are liberated through the ostiole in a mucilaginous mass. They are hyaline to sub-hyaline, straight to rarely slightly curved, rounded at both ends. They range from 5-10 μ in length and 2·5-3 μ in width.

Conidiophores. The conidiophores arise from a hyaline sporogenous layer of cells which is supported by a colourless pseudoparenchymatous sheath lining the dark wall of the pycnidium. The sporogenous layer is composed of very small and narrow cells from which the conidiophores arise. The conidiophores are simple and unicellular.

Mycelium. The mycelium permeates the entire area of the leaf spot and even extends slightly to the surrounding area. The hyphae are both inter- and intra-cellular and septate and branch irregularly.

ISOLATION AND INOCULATION EXPERIMENTS

Isolation. The fungus was readily brought into culture by transferring surface sterilized bits of affected portions of leaves to oat agar plates. A large number of isolations were made, all of which yielded the same fungus.

Inoculation experiments. Inoculation experiments were carried out on *papaya* plants both in the laboratory and in the fields. For conducting the inoculation experiments in the laboratory plants were raised in pots and then subjected to infection. Two methods were followed: spore suspension in sterile water was sprayed on the leaves, or a culture containing the mycelium and crushed pycnidia was placed on unwounded surfaces of the leaves. All the plants after inoculation were kept closed in a glass house, which was kept moist by occasional spraying with sterile water. After 24 to 48 hours the plants were removed from the glass house and kept in the open. They were occasionally sprayed with sterile water.

Fifty-two plants were treated in this way. All the plants took infection. When cultures containing mycelium and crushed pycnidia were used as inocula the signs of infection were visible in 4 to 6 days; in case of spore suspensions the symptoms were apparent after 12 to 17 days. The inocula were placed both on the upper and the lower surfaces of the leaves but infections were successful only when the inocula were placed on the upper surface. All the controls remained healthy.

In the field, infection experiments were carried out by means of bits of culture containing mycelium and crushed pycnidia of the fungus. Leaves of the plants were first sprayed with sterile water and then the inocula were placed at selected places on the upper surfaces of the leaves by a sterile needle. The inocula were thereafter covered with small pieces of sterile absorbent cotton made wet by dipping in sterile water. The inoculated leaves were sprayed with sterile water from time to time in order to keep the inoculated places moist. After four to six days, infection became visible. In all 217 inoculations were made on a number of plants in the different plantations at Haflong and Jatinga in the North Cachar Hills and 97 per cent of the inoculations were successful. Plants that were left uninoculated but otherwise given the same treatments and were standing in close proximity to those inoculated remained healthy.

All these experiments prove beyond doubt that the fungus is an active parasite.

From all the infected plants the original fungus was reisolated in every case.

GROWTH IN CULTURE

The fungus was grown on oat agar and on *papaya* leaf juice agar. Mycelial growth was good on both the media. Aerial growth was scanty, much of it was submerged and of a spreading nature. Pycnidial formation was more abundant on *papaya* leaf juice agar than on oat agar.

The mycelium in both the media consisted of septate, pale green hyphae which branch irregularly. The mode of branching, the irregular form, size and the bulging of the cell walls are very characteristic. The young hyphae are long, slender; septa are rare and the walls are not constricted. Anastomosis is frequent along the walls.

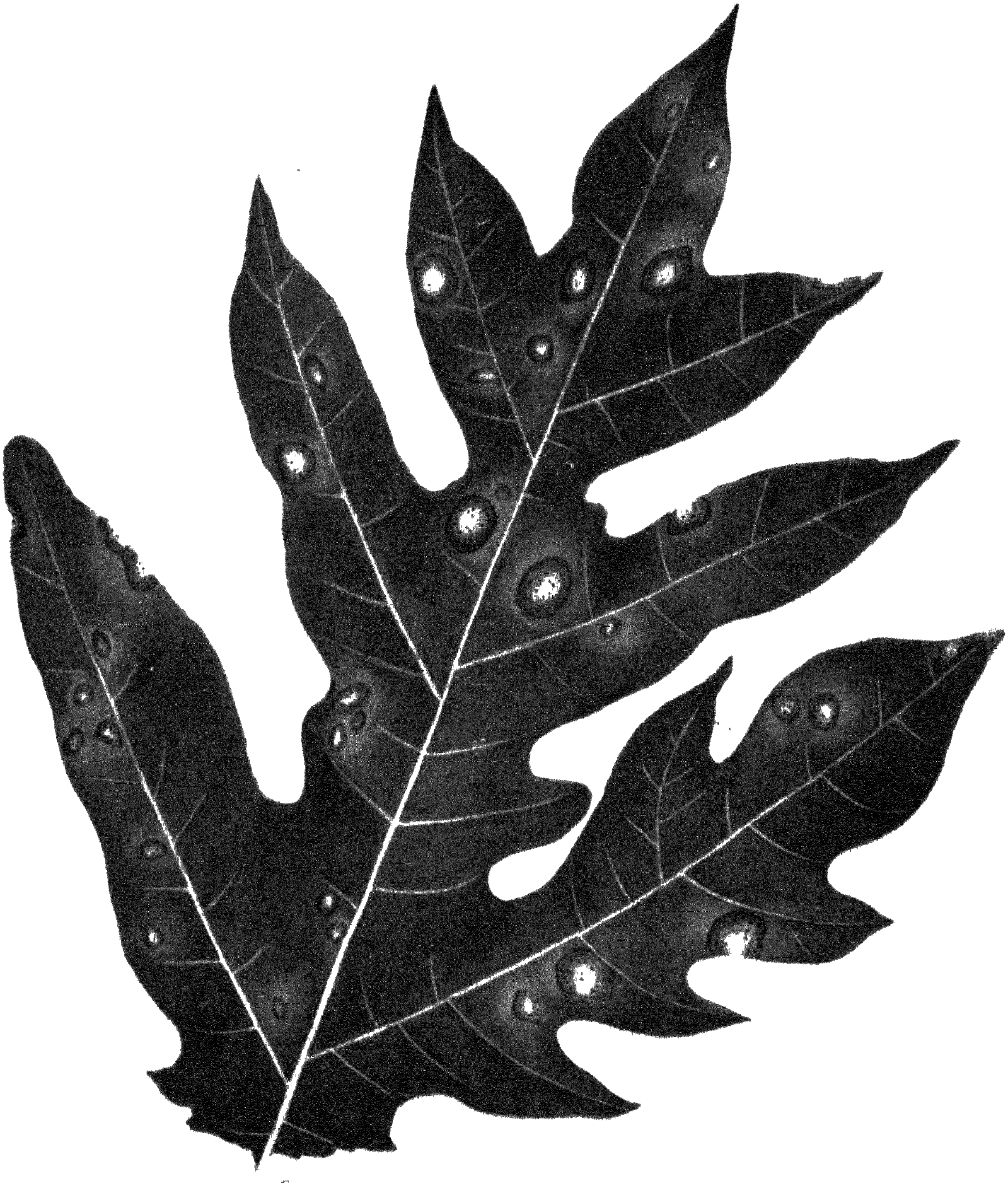
In the old hyphae the cells are short and thick and occupied by large globules of a greenish colour; septation is frequent and the walls are prominently constricted at the septa and at the bases of the short, stout branches that arise at irregular angles.

In culture the pycnidial formation starts on the 5th or 6th day. The pycnidia are light brown at first but with age the colour deepens and finally they turn dark brown to almost black. They are slightly bigger than those formed in nature measuring 90-127×67-107 μ. Each pycnidium has an ostiole and a short neck. Some are spherical but in the majority of cases they are sub-globose.

The pycnospores are formed in abundance within the pycnidia. They are liberated from the pycnidia through the ostiole in a mucilaginous mass. They are hyaline to sub-hyaline, straight to rarely slightly curved and rounded at both ends. They measure from 5 to 10 μ in length and 2·5 to 3 μ in width.

IDENTIFICATION OF THE PARASITE

On going through the relevant literature it was found that two species of *Phyllosticta* have been recorded on *Carica papaya.* They are *Phyllosticta Papayae* Sacc. and *P. Caricae-Papayae* Allesch. The reported spore measurement data of these two fungi along with that of *Phyllosticta* sp. from North Cachar Hills are recorded in Table I.



Symptoms of the disease-

TABLE I

Comparative spore measurements of species of Phyllosticta *occurring on* Carica papaya

Fungus	Dimensions of spores	Colour of spores
Phyllosticta Papayae .	2·5—3·5 × 1 µ	Hyaline
P. Caricae-Papayae .	3·0—4·0 × 1 µ	Hyaline
Phyllosticta **from North Cachar Hills**	5·0-10·0 × 2·5-3µ	Hyaline to sub-hyaline

It is evident from the comparative spore measurement data presented above that the spore measurements of *Phyllosticta* from North Cachar Hills take it outside any probable variation of *Phyllosticta Papayae* and *P. Caricae-Papayae.*

A few diseased *papaya* leaves were sent to Mr E. W. Mason, Imperial Mycological Institute, Kew, Surrey, England, for help in the identification of the parasite. He wrote 'I cannot find that it has been described under any name in our systematic lists'. The fungus is therefore, considered a species new to science for which the name *Phyllosticta sulata* is proposed.

Phyllosticta sulata Chowdhury Sp. Nov.

Pycnidia first sub-epidermal, later becoming erumpent, globose to sub-globose, dark brown to black, 80-115 × 60-95 µ, usually with distinct ostioles. Pycnospores unicellular, hyaline to sub-hyaline, straight to rarely slightly curved, rounded at both ends, measuring 5-10 × 2·5-3 µ.

Parasitic on the leaves of *Carica papaya* L. Haflong, Assam, 7 November 1940. Collected by S. Chowdhury.

Type specimen deposited in the Herb. Crypt. Ind. Orient., Imperial Agricultural Research Institute, New Delhi.

Pycnidiis primo sub-epidermalis, tunc erumpentis, globosis vel sub-globosis, atro-brunneis vel nigris, 80-115 × 60-95 µ, plerumque distincte osteolatis. Pycnosporidiis unicellularis, hyalinis vel sub-hyalinis, rectis vel sub-curvatis, basis et apicis rotundatis, 5-10 × 2·5-3 µ.

Parasiticis in foliis *Caricae papayae* L., Haflong, Assam, 7 November 1940. S. Chowdhury leg.

Typus in Herb. Crypt. Ind. Orient., Imperial Agricultural Research Institute, New Delhi.

PERPETUATION AND DISSEMINATION OF THE PARASITE

Intensive studies to determine the mode of perpetuation and dissemination of the parasite have not been undertaken. Limited studies and circumstantial evidence, however, have demonstrated that the parasite lives over on infected plant debris in the soil.

In January 1941 pieces of naturally infected leaves were wrapped in tissue paper and carried through the rest of the winter and the summer months under the following conditions:

(i) Hung on the tree in the open.

(ii) Placed on the surface of the ground.

Isolations were made from these materials in August and September 1942 and the fungus was recovered in every instance. Inoculation experiments were carried out by using these isolations as inocula and in 92 per cent cases the infections were successful.

In the *papaya* plantations in the North Cachar Hills, where plants are grown on hill slopes, sanitary methods of cultivation are not at all followed. Fallen leaves of *papaya* plants are allowed to remain and rot in the ground. In every plantation one comes across piles of fallen leaves lying about. From these piles a large number of isolations were made during the years 1941 and 1942, beginning from February and ending in September. In all cases the fungus was recovered. It can thus safely be concluded that the parasite perpetuates in the plant debris in the plantations.

Careful observations indicate that the parasite is disseminated through the agency of wind. The disease has been found to appear every year during the later part of September. During this time there is scanty rainfall but there is an excessive fall of dew, which helps the pycnidia to burst, liberating the pycnospores and allowing them to germinate.

CONTROL AND PREVENTION

From these studies it will be evident that the disease can be controlled by systematic collection and destruction by burning of the affected leaves that lie on the ground and serve as a source of inoculum.

Preventive methods have been carried out with success. In five plantations 20 to 25 plants in each of the plantations were carefully sprayed with one per cent Bordeaux mixture during the latter part of August, 1941; they were given a second spraying on 15 September, a third spraying on 15 October and a fourth on 15 November. Spraying was done carefully so that the surfaces of sprayed leaves were uniformly and thoroughly covered with the spray fluid. It was found that the sprayed plants were either absolutely free from infection or there were fewer spots on them in comparison with unsprayed control plants in close proximity. The spray trials conducted in 1942 have further brought out the fact that three sprayings (latter part of August, 15 September and 15 October), if carefully and thoroughly done, are sufficient for keeping the disease in check. But if perchance there is a heavy shower immediately after giving a spray it becomes necessary to give the plants an additional spray immediately after the rain.

Above all it has been found that unless efforts are made to destroy the source of infection by the systematic collection and destruction of the affected leaves and burning them, it is not easy to keep the disease under control and to check or minimize the loss it causes.

SUMMARY

A leaf spot of *Carica papaya* L., due to a species of *Phyllosticta*, has been found to occur at Haflong in the North Cachar Hills.

Symptoms of the disease are described. The fungus has been isolated and inoculation experiments carried out. It has been found that the fungus is a virulent parasite.

The fungus has been studied both in culture and on the host and found to be a species new to science, which is given the name *Phyllosticta sulata*.

The parasite survives in the affected leaves lying in the plantations and is disseminated by wind.

It can be controlled by systematic collection and destruction of the affected leaves and prevented by spraying the plants with one per cent Bordeaux mixture.

ACKNOWLEDGEMENTS

My thanks are due to Dr B. B. Mundkur, Imperial Agricultural Research Institute, New Delhi, for critically going through the manuscript and for valuable suggestions, to Mr E. W. Mason of the Imperial Mycological Institute, Kew, Surrey, England, for help rendered in the identification of the fungus and to Father F. S. Pew, S. J. of the St. Xaviers College, Calcutta, for the Latin diagnosis.

COMPARATIVE STUDIES OF SOME INDIAN PLOUGHS WITH DYNAMOMETER

By P. S. RAO, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 3 January 1944)

(With thirty-six text-figures)

INTRODUCTION

As the main operation of stirring or loosening of the soil in agricultural fields for sowing purposes can best be done with plough only, the plough has become an indispensable implement for the agriculturist. Recorded history does not give the origin or the exact date of its coming into existence. However, it appears to have existed in the eastern countries as early as 2500 B. C. In Ramayana its name is mentioned as *Nagali* and in Mahabharata as *Hala*, which terms are still in use in many parts of India. When the idea of agriculture and cultivation entered the mind of man, he tried to prepare seed beds with the help of crowbars and by beating the bulky clods into powder with hammers and axes. This practice of beating the clods appears to have existed in England even in the Saxon period. As man progressed, his needs for agricultural produce multiplied, he began to make attempts to improve upon the primitive devices of seed-bed preparation and succeeded in evolving a plough based on lever principle. From literature it appears that the earliest plough was an irregularly bent branch of a tree. Later on, with the advance of science and civilization, people realized that the economic prosperity of a country depends to a considerable extent on the increased output of the agricultural products. With such an end in view every country took up the problem of improving the plough by applying scientific principles to suit its local conditions and the power available for work. In Europe and America extensive efforts have been made to improve the plough from the draught as well as the efficiency point of view. With the harnessing of mechanical power to agriculture various attempts have been made to improve the plough by modifying shares, by inserting mouldboards and finally manufacturing them with iron. The discovery of high grade steel has made possible further improvement in the shape of shares. Based on similar principles a number of implements have been designed, including single and multifurrow ploughs. But in India, Egypt and other Asiatic countries little progress in the improvement of plough has been made. Some improvement can, nevertheless, be said to have been made because they are now made in three parts and assembled together instead of a single piece of the primitive type. The strength has been increased to work in all types of soils and at greater depths. A share, i.e. an iron rod, is also used to protect the penetrating end of the wedge from wear and tear and also to ensure deeper cutting. But no experimental records exist to show the processes of evolution to the present models. We find that different provinces in India, and even different places in the same province, have different types of ploughs, some differing in weight, some in size of the wedge, some in length and some in shape.

It will thus be seen that the plough, the universal cultivating implement, was first roughly made out of a branch of a tree, then by the crude carpenter of the early times, and now it is manufactured by trained engineers with all the modern appliances and scientific resources of civilization.

LITERATURE

In foreign countries a systematic study on the shape of ploughs has been made with the help of mechanics and mathematics. Draught measurements were recorded by dynamometer as early as 1840 by Pusely [White, 1918]. The annual report of the New York State Agricultural Society for 1867 [White, 1918] contains a treatise on the geometrical construction of the surfaces of many historical plough bottoms, but no attempts have been made to classify these surfaces on the basis of their mathematical forms. White [1918] has evolved mathematical equations regarding the shape of mould boards and has also given methods for generating suitable mould board surfaces for different soils. In 1920-23, Davies [1924] investigated the relation between (*i*) draught and depth (*ii*) draught and width of the furrows, and showed that a linear relation exists between them. Keen and Haims [1925] carried out some work at Rothamsted and established a hyperbolic relationship between moisture percentag eanddraught. Nichols [1930 ; 1931] studied the various soil constants which would indicate the physical factors affecting tillage and was led to the conclusion that a definite relation exists between friction value, shear resistance to compression and the Atterberg consistency constants. He also mentioned that the general reaction of the soil to an implement was a function of the physical properties indicated by the Atterberg constants and could be predicted for any moisture content. In further dynamic studies of the soil, he established a relationship between friction and hardness of metal of the plough wedge or share and the colloidal contents of the soil. According to him when the colloidal content exceeds 32 per cent, the friction increases slightly and is considered to be the limit for that factor. He found that the polish also affects the frictional value in heavy soils but as no measure of the polish was available no mathematical formula for its effect was obtained.

In Egypt, ploughing is done by wooden ploughs resembling much the Indian ploughs, except that the share is spoon-shaped, as it has to work in soft soils. When the members of the Royal Commission on Agriculture in India [Middleton, Calvert and Gangulee, 1928] were touring Egypt they were informed that attention had been given to the possibility of improving the local plough but could not be done at the price at which the competing implements would have to be sold in Egypt.

In India, Charley did some work in Madras mostly on foreign ploughs, but the data and methods followed in conducting these experiments are not available. Godbole [1913] designed a new plough and compared it with the existing Deccan plough by finding the average resistance required to open unit area of the cross-section of the furrow with the help of a spring balance dynamometer having a pointer moving on a calibrated circular dial. He has mentioned that the centre of gravity of the plough should be very near the point where the beam is fixed to the body. Clouston [1906], after making comparative studies of foreign and Indian agricultural implements, expressed the view that the manufacturers of foreign ploughs have not considered the Indian agriculturists' point of view. He modified the foreign ploughs to suit Indian conditions by introducing a wooden beam in place of chain and iron beam and finally was of the opinion that the Swedish plough with the above modifications gave satisfactory performance.

However, he did not give any data to substantiate his conclusions. Henderson [1909] designed a wooden plough based mainly on experience. This plough works satisfactorily on irrigated tracts of Sind. On the basis of theoretical arguments Miller Brownlie [1922] was of the opinion that a plough having the line of draw-bar-pull coinciding with that of the resultant of the forces due to the soil on the plough, will work efficiently even if the ploughman is not very attentive. Mayadas and Hansraj [1931] carried out some tests to judge the efficiency of some improved ploughs by finding the average resistance per unit area of the cross-section of furrow and horse power required to work them. In these experiments they used spring-balance-dynamometer similar to the one used by Godbole. They also worked them over equal areas and compared the nature of tilth and the time taken by them. Mason Vaugh, Agricultural Engineer at Naini Institute, Allahabad, did some work on ploughs but he has concentrated his attention on iron ploughs only. He has designed a plough with four adjustments which can be used for four different operations with slight adjustment of the parts. Cliff [1927], while designing a cultivator, studied the relative merits of all the implements that would be useful on an agricultural farm. He found that the Indian ploughs leave (Δ-shaped) ridges between furrows untouched and if the stirring was to be done at a uniform depth throughout the field, a number of cross-ploughings were required and this would take more time. In his view all foreign designs were unsuitable to Indian condition and a suitable design would find a good market in India irrespective of its cost. However, he did not attempt to design a new plough as his efforts were concentrated on his cultivator. Some dynamometer tests on agricultural implements were conducted at Pusa (Bihar), but most of these tests were restricted to the utility of tractors and foreign implements for Pusa conditions.

OBJECTS AND METHODS

From the brief review of literature given above it will be seen that much work has not been done in India on *desi* ploughs used in different parts of India. With the object of making a comparative study, a number of *desi* ploughs were collected at Delhi from different parts of India and attempts are made in this paper to classify them from (*i*) constructional, (*ii*) soil, (*iii*) climatic, (*iv*) crop, (*v*) depth and width of furrow, and (*vi*) draw-bar-pull points of view.

Before classifying the ploughs, we will first give brief description of all the ploughs used in these experiments. The notations adopted are indicated in Fig. 35.

BRIEF DESCRIPTION OF PLOUGHS WITH OTHER DETAILS

(1) *Bellary plough* (*Madras*). The dimensional diagram is given in Fig. 1. The wedge and the body are made in one piece and the beam is fixed to the body at a distance of 5 in. from the inner bend between body and wedge. The body, wedge and beam are made of acacia, i.e. *babul* wood. The beam is of rectangaular cross-section 3 in. × 4 in., its length being 9 ft. 2 in. The thickness and width of the body in the direction and perpendicular to beam are 5 in. and 7 in. respectively at the place where the beam is fixed to it. The wedge is a pyramid of equilateral triangular cross-section having the maximum section 6 in. side and the vertex of the section facing downwards. The length of the wedge up to the body is 32 in. and up to its intersection with the beam is 40 in. The angle of the wedge, i.e. the face angle of wedge at the penetrating point is 16° and the angles which the wedge makes with the body and beam are 135° and 42·5° respectively. A handle is fixed to the beam at the back of the body. The length of the share, i.e. an iron rod used to protect the penetrating point of the wedge from wear and tear, is 26·5 in. The weight of the plough is 81·5 lb. This plough is used in black soils of Bellary and Kurnool districts. The crops generally grown in these districts are *jonna* (*Andropogon sorghum*), *Tenai* (Italian millets) and cotton. The ploughing is usually done to a depth approximately 8 in. The plough is used mainly in rainfed area. The average monthly rainfall, on the basis of 37 years, for these districts is as follows: January = 0·59 in., February = 0·32 in., March = 0·48 in., April = 1·44 in., May = 2·36 in., June = 1·46 in., July = 1·46 in., August = 1·13 in., September = 1·51 in., October = 6·41 in., November = 3·75 in., and December = 1·18 in. Two pairs of Mysore bullocks, having a live weight 700 to 900 lb., are used to work this plough as it is a heavy plough.

(2) *Coimbatore plough* (*Madras*). The dimensional diagram is given in Fig. 2. The wedge and the body are made in one piece and the beam is fixed to the body very near the inner bend between the wedge and body. The wedge and the body are made of acacia and the beam from salwood. The beam is of rectangular cross-section 1½ in. × 3 in. very near the body, and is of oval section for the remaining portion, the length being 11 ft. 7 in.

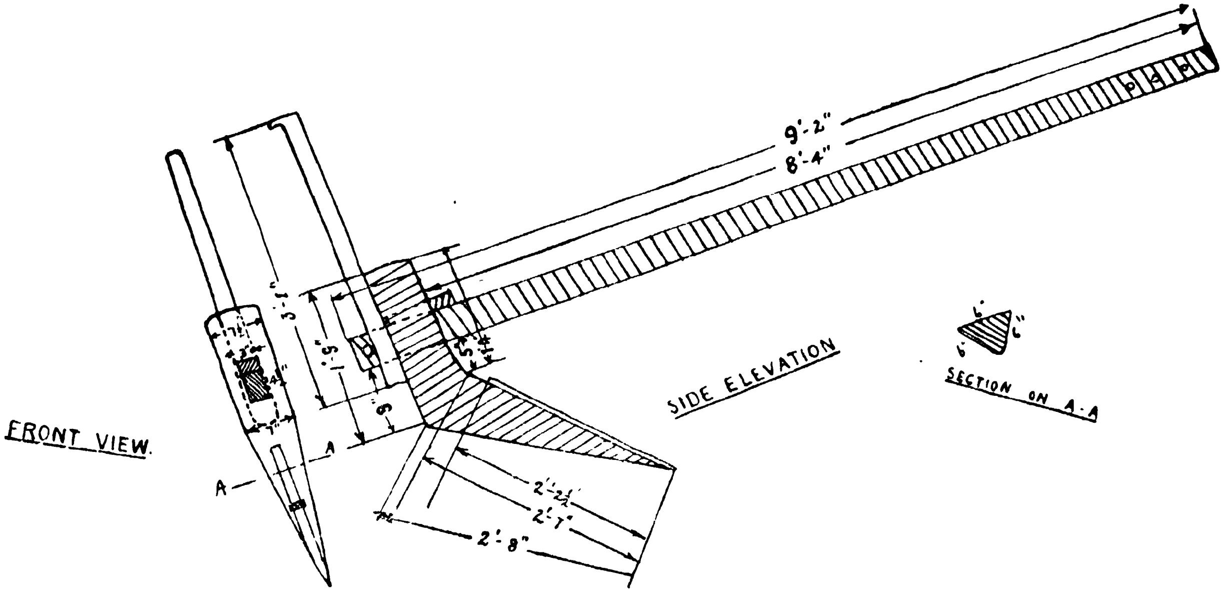


FIG. 1. Heavy country plough, Bellary (Madras)

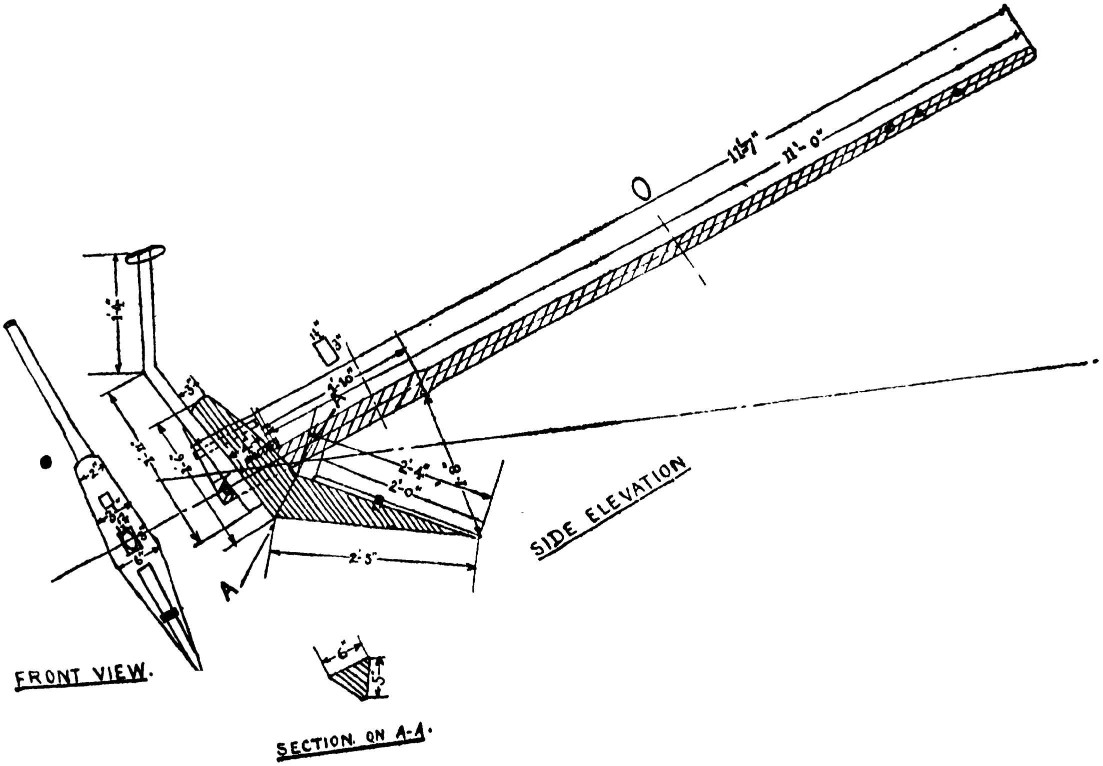


FIG. 2. Country plough, Coimbatore (Madras)

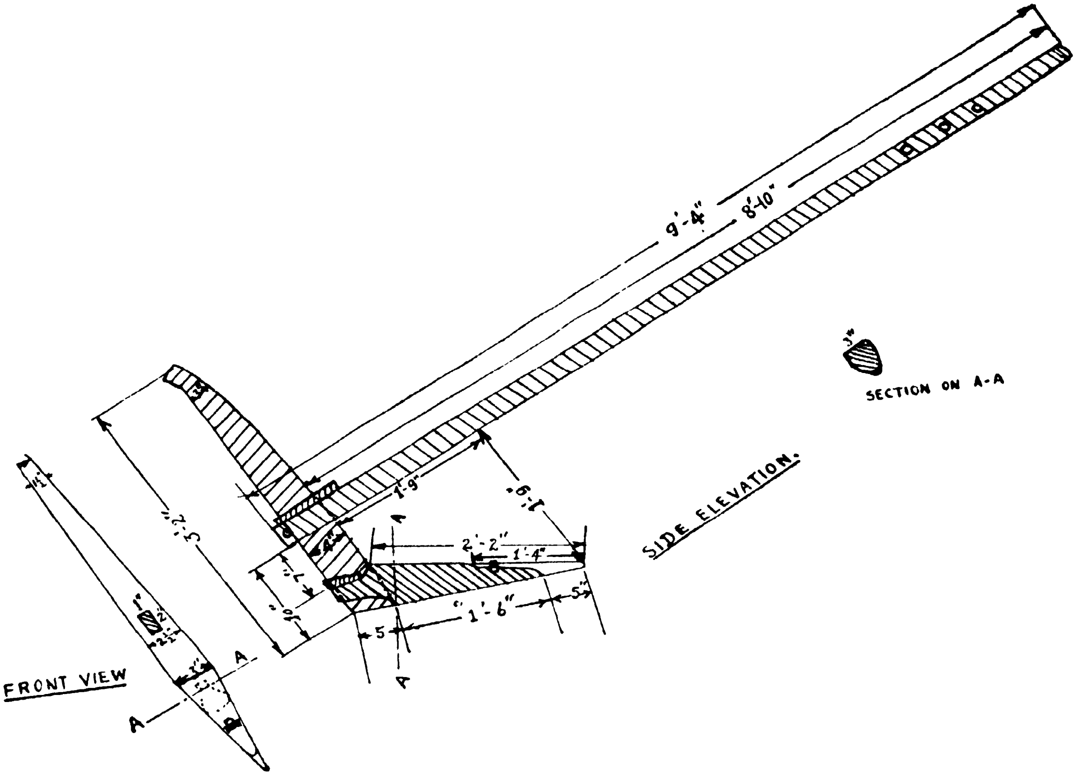


Fig. 3. Country plough, Dohad (Bombay)

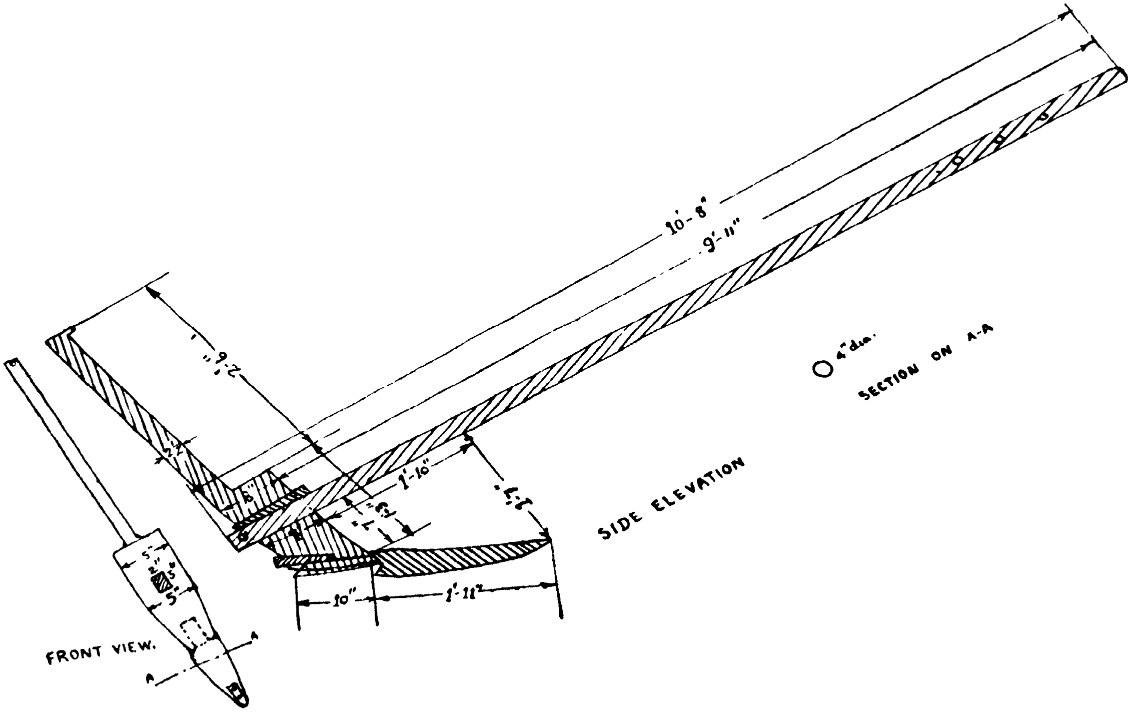


Fig. 4. Country plough, Baroda

The body, at the place where the beam is fixed to it, is trapezium in section 6 in. × $4\frac{1}{2}$ in. × 3 in. × $4\frac{1}{2}$ in. The wedge is pyramid of an isosceles triangular section, having the sides and base at maximum section 5 in. and 6 in. respectively and the vertex facing downwards. The face angle of the wedge is 12·4° and the angles which the wedge makes with the body and beam are 153° and 40·96° respectively. The length of the wedge up to the body is 29 in. and up to its intersection with the beam 34 in. A handle is fixed to the beam at the back of the body. The length of share is 24 in. The weight of the plough is 37·4 lb., having the centre of gravity very near the inner bend. This plough is used in light, heavy, black, red, garden and wet lands of Coimbatore and other neighbouring districts. The crops generally grown are paddy, cotton, pulses and cereals. The ploughing is done when the soil is fit to a depth of 3 in. to 4 in. It is used in both irrigated and rainfed tracts. The average monthly rainfall is as follows: January = 0·59 in., February = 0·32 in., March = 0·48 in., April = 1·44 in., May = 2·36 in., June = 1·46 in., July = 1·46 in., August = 1·13 in., September = 1·51 in., October = 6·41 in., November 3·75 in., and December = 1·18 in. A pair of Kangayam bullocks of live weight 800-900 lb. each is used for light soils and 1000 to 1200 lb. for heavy soils to work this plough.

(3) *Country plough, Dohad (Bombay).* The dimensional diagram is given in Fig. 3. The body and the wedge are made in two pieces, and assembled together such that they appear to have been made in one piece. The beam is fixed to the body at a distance of 7 in. from the inner bend between body and wedge. The plough is made of salwood. The beam is of rectangular cross-section 1 in. × 2 in. and its length being 9 ft. 4 in. The body and the handle are made in one piece and the body at the place where the beam is fixed to it is of rectangular cross-section 4 in. × 3 in., and at the place where the wedge is fixed to it is of rectangular section 5 in. × 3 in. The wedge is very narrow having a cross-section of more than half an ellipse cut by a line parallel to minor axis, the flat face facing upwards. The face angle of the wedge is 8·2° and the angles which the wedge makes with the body and beam are 122° and 43° respectively. The length of the wedge up to the body is 18 in. and up to its intersection with the beam is 35 in. The length of share is 16 in. and protrudes 5 in. outside the wedge. The weight of the plough is 28·7 lb. This plough is used in soils varying from light to black of the eastern parts of Panchmahals. The crops generally grown are maize, groundnuts, paddy, wheat, gram; and ploughing is done to a depth of 4 in. to 6 in. in dry tracts. It is used in both irrigated and rainfed tracts. The average monthly rainfall is as follows: January = 0·11 in., February = 0·16 in., March = 0·08 in., April = 0·04 in., May = 0·51 in., June = 4·34 in., July = 8·87 in., August = 7·60 in., September = 5·58 in., October = 1·10 in., November = 0·19 in., and December = 0·11 in. A pair of Malvi bullocks with a live weight of 700 lb. and with a height of 4 ft. is used to work this plough.

(4) *Country plough, Baroda (Bombay.)* The dimensional diagram is given in Fig. 4. The wedge and body are made in two parts and assembled together as shown in the diagram. The beam is fixed to the body leaving a clearance of 7 in. from the place where the wedge is fixed to the body. The beam is of rectangular cross-section 2 in. × 3 in., its length being 10 ft. 8 in. The body is a rectangular solid with cross-section 8 in. × 5 in. and 10 in. × 4 in. where the beam and wedge are fixed to it respectively. The body and the handle are made in one piece. The wedge is approximately a cone having 4 in. diameter at the maximum section, the angle of cone being 13·3°. The angles which the wedge makes with the body and beam are 140° and 37·6° respectively. The length of the wedge up to the body is 23 in. and up to its intersection with the beam is 36 in. The length of the share is 6 in. The weight of the plough is 50·7 lb. This plough is used in light alluvial soils (known as Gorat) of Baroda and surrounding places. The crops generally grown are *bajara*, *kodra* (*Eleusine coracana*), *bawta* and tobacco. The ploughing is done usually to a depth of 5 to 6 in. when the moisture content of the soil varies from 15 to 30 per cent. It is used mainly in rainfed areas and the average monthly rainfall is as follows: January = 0·40 in., February = 0·00 in., March = 0·00 in., April = 0·00 in., May = 0·00 in., June = 4·69 in., July = 14·45 in., August = 3·65 in., September = 10·00 in., October = 1·06 in., November = 0·00 in., and December = 0·00 in. A pair of bullocks with 54 in. height behind hump, and girth of 75 in. having a length of 61 in. from shoulder to pin bone, and a live weight varying between 800 to 1200 lb. each is used to work this plough.

(5) *Country plough, Indore (Central India).* The dimensional diagram is given in Fig. 5. The wedge and the body are made in two pieces and assembled together with a fine joint so that they

appear to have been made in one piece. The beam is fixed to the body at a distance of 7½ in. from the inner bend between the wedge and body and is of rectangular cross section 1½ in. × 3 in., its length being 10 ft. 4 in. The body is a rectangular solid with cross-sections 4 in. × 3 in. and 5 in. × 2 in. at the places where the beam and wedge are fixed to it respectively. The body and handle are made in one piece. The wedge is similar to that of Dohad, with flat face facing upwards as shown in Fig. 5. The length of the wedge up to the body is 20 in. and up to its intersection with the beam is 30 in. The face angle of the wedge is 10°, and the angles which the wedge makes with the body and beam are 133° and 42·5° respectively. The length of the share is 6 in. The plough is made of salwood and its weight is 56·9 lb. This plough is used in medium black to heavy black clay soils of Malwa plateau. The crops generally grown are *jowar*, cotton, wheat, gram, linseed, peas, etc. Ploughing is done occasionally as annual ploughing is not practised except for special crops such as sugarcane, etc. When ploughing is done, it is usually done after rains and to a depth of 5 in. to 6 in. This plough, though mainly used in rainfed tracts, is used in irrigated tracts as well. The average monthly rainfall is as follows: January = 0·28 in., February = 0·18 in., March = 0·06 in., April = 0·14 in., May = 0·58 in., June = 5·70 in., July = 9·87 in., August = 8·01 in., September =6·53 in., October = 1·15 in., November = 0·41 in., and December = 0·21 in. A pair of Malvi bullocks with an average length of 5 ft. 2 in., height 4 ft. 10 in. and live weight of about 1,224 lb. each is used to work this plough.

(6) *Sarkar plough, Sind* (*Egyptian type*). The dimensional diagram is given in Fig. 6. This model is completely different from the other Indian ploughs and is known as Egyptian type. This was designed by Henderson. There is no body and the wedge serves both purposes. The beam and the wedge are fixed together by means of a bolt rod at a distance of 16 in. from the pointed edge of the wedge and another bolt at the other end of wedge. This method of tightening enables us to alter the angle between the beam and wedge whenever required. The beam is of rectangular cross-section 2 in. × 3 in., its length being 9 ft. The cross-section of the wedge perpendicular to its length is four sided, one of the sides being an arc of a circle and facing downwards. The cross-section of the wedge along its length is a triangle up to 16 in. from the pointed end and a rectangle for the remaining portion. The total length of the wedge is 30 in. The angle which the wedge face makes with the beam is 40·96°. A flat iron plate is used as share to protect the wedge. A separate handle is fixed to the beam at a distance 8 in. from the bolt rod. The weight of the plough is 33·3 lb. This plough is used in soils varying from sandy loam to clay loam of Hyderabad, Tharparkar and Nawab Shah districts of lower Sind. The crops generally grown are cotton, wheat and oilseeds and ploughing is done to a depth of 3 to 3½ in. after irrigation. The plough is used in irrigated tract only. The average monthly rainfall is as follows: January = 0·20 in., February = 0·27 in., March = 0·24 in., April = 0·05 in., May = 0·20 in., June = 0·45 in. July = 2·85 in., August = 2·12 in., September = 0·60 in., October = 0·02 in., November = 0·06 in., and December = 0·06 in. A pair of Karachi bullocks with a live weight of 800 to 900 lb. and height of 4 ft. 5 in. each or a pair of Tharparkar bullocks with a live weight 900 to 1000 lb. and height 4 ft. 8 in. each is used to work this plough.

(7) *Kannar plough* (*Sind*). The dimensional diagram is given in Fig. 7. This is an iron plough with a modified mould board and a wooden beam. The share and mould board are attached tightly to the body with the help of bolts and nuts. A wooden beam of rectangular cross-section 2 in. × 3 in. is fixed to the body by means of bolt and nuts and its length is 9 ft. 5 in. The furrows opened by this plough are not triangular in cross-section as is the case with the other Indian ploughs. The share of this plough opens furrows 4 in. to 6 in. wide at the bottom. Other particulars can be seen from the diagram. The weight of the plough is 37·9 lb. This plough is used in rainfed areas and also in the same tracts as the Sarkar plough, with the same animals. The ploughing is done to a depth of 3½ in. to 4 in.

(8) *Native plough* (*Sind*). The dimensional diagram is given in Fig. 8. The wedge, body and the handle are made in one piece. All the three form an arc when viewed from the side of the plough. The beam is fixed to the body by means of cotters and the cross-section of the body where the beam is fixed to it is 4 in. × 4 in. The beam is of rectangular cross-section 1½ in. × 2½ in. and its length is 9 ft. 9 in. The wedge is a pyramid of a pentagonal cross-section with four equal sides. The equal sides at the maximum section are 3 in. each, the fifth side which faces upwards measures 5 in. The length of the wedge up to the body is

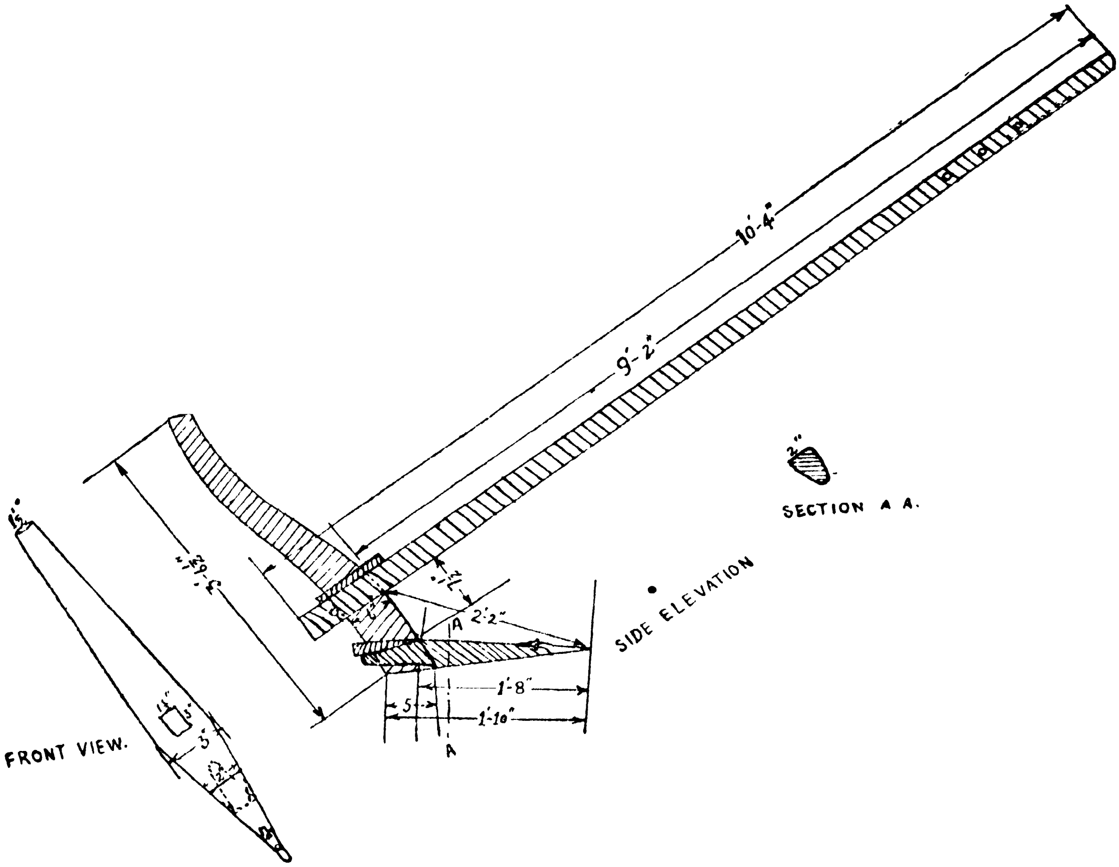


Fig. 5. Country plough, Indore

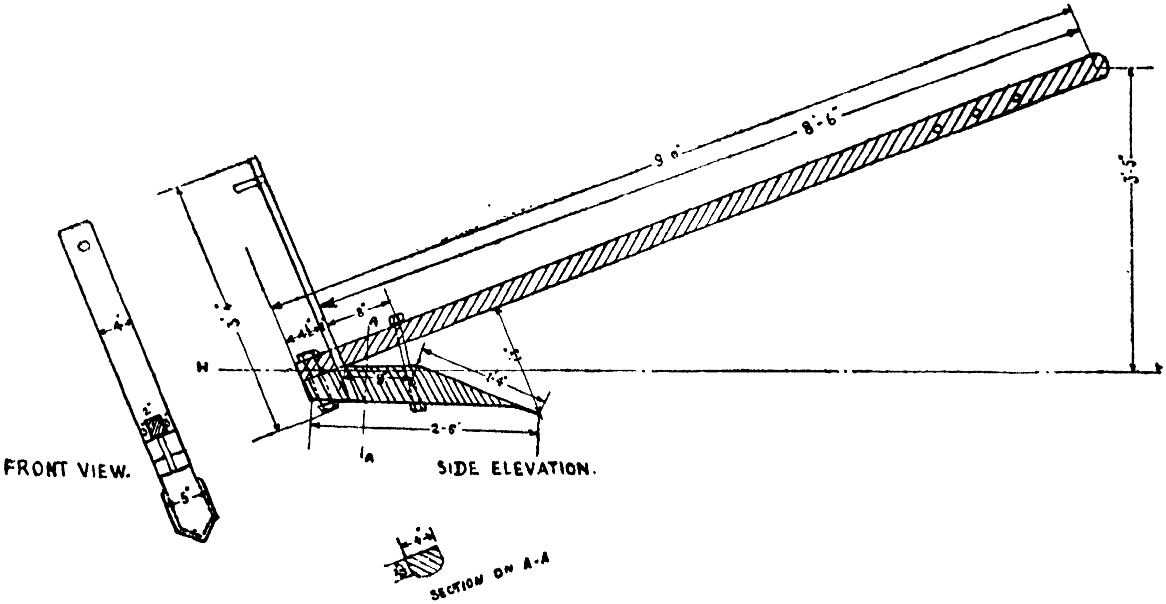


Fig. 6. Sarkar plough, Sind

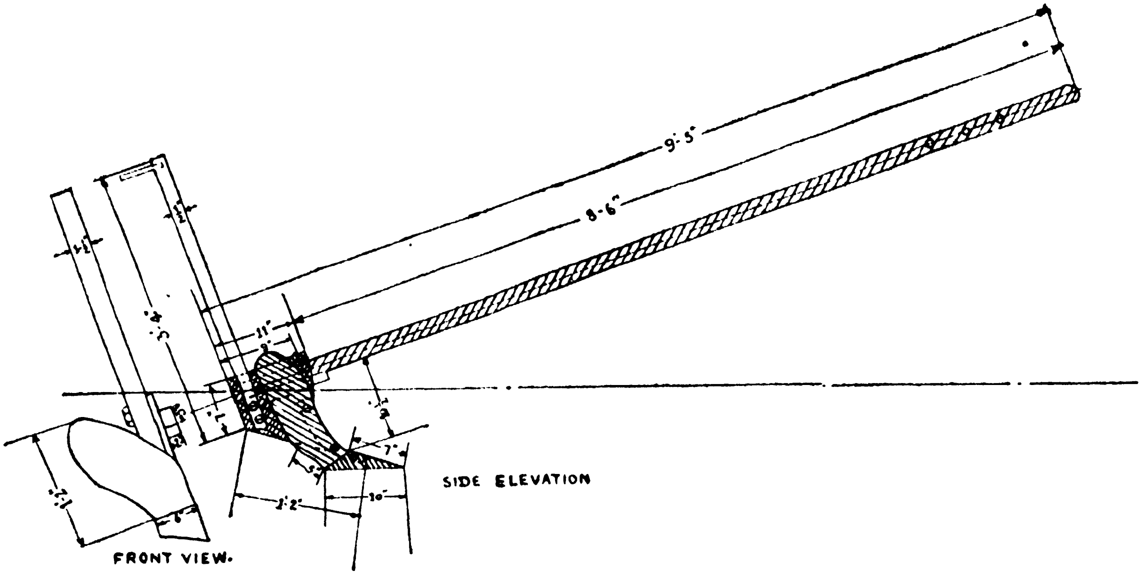


Fig. 7. Kannar plough, Sind

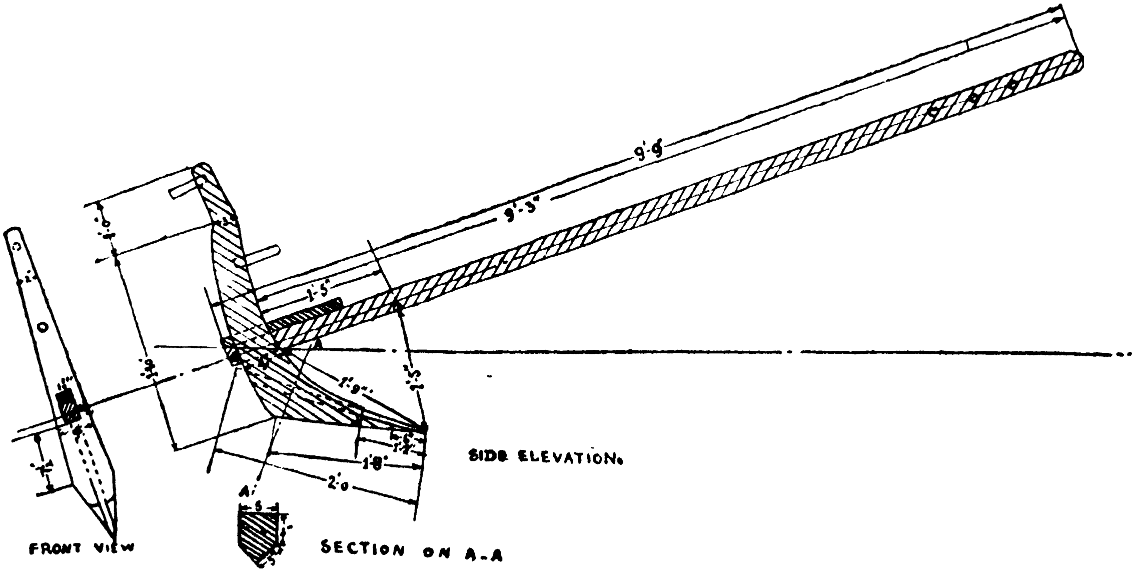


Fig. 8. Native plough, Sind

20 in. and up to its intersection with the beam is 23 in. The angle which the wedge makes with the body and beam are 140° and 46·8° respectively. The face angle of the wedge is 20°. The length of the share is 24 in. and the weight of the plough is 35·4 lb. This plough is used throughout Sind province in dry and wet tracts. Other conditions are similar to that of Sarkar and Kannar ploughs.

(9) *Country plough* (*N.-W. F. P.*). The dimensional diagram is given in Fig. 9. The wedge and body are made in one piece. The whole piece is a crude irregularly bent wood with irregular shape, one end of which is used as body and the other end is chipped to form the wedge. The beam is made from three curved pieces and the total length of the beam is 11 ft. 7 in. The length of wedge up to the beam is 11 in. An iron rectangular plate with a conical pointer is used as a coulter. The length of the share is 12 in. and projects 5 in. beyond the wedge. The weight of the plough is 47·8 lb. This plough is used all over N.-W. F. Province and is worked by camels. This plough is similar to Sarkar Sind excepting the beam and share. The share is very pointed and the beam is curved in this case.

(10) *Country plough. Karnal* (*Punjab*). The dimensional diagram is given in Fig. 10. The wedge and body are made in two pieces and assembled together in such a way that they appear to have been made in one piece. The beam is fixed to the body at a distance of 6½ in. from the inner bend between body and wedge. The beam is of rectangular cross-section 3 in. × 4 in. and its length is 10 ft. 10 in. The body and the handle are made in one piece and the width and the

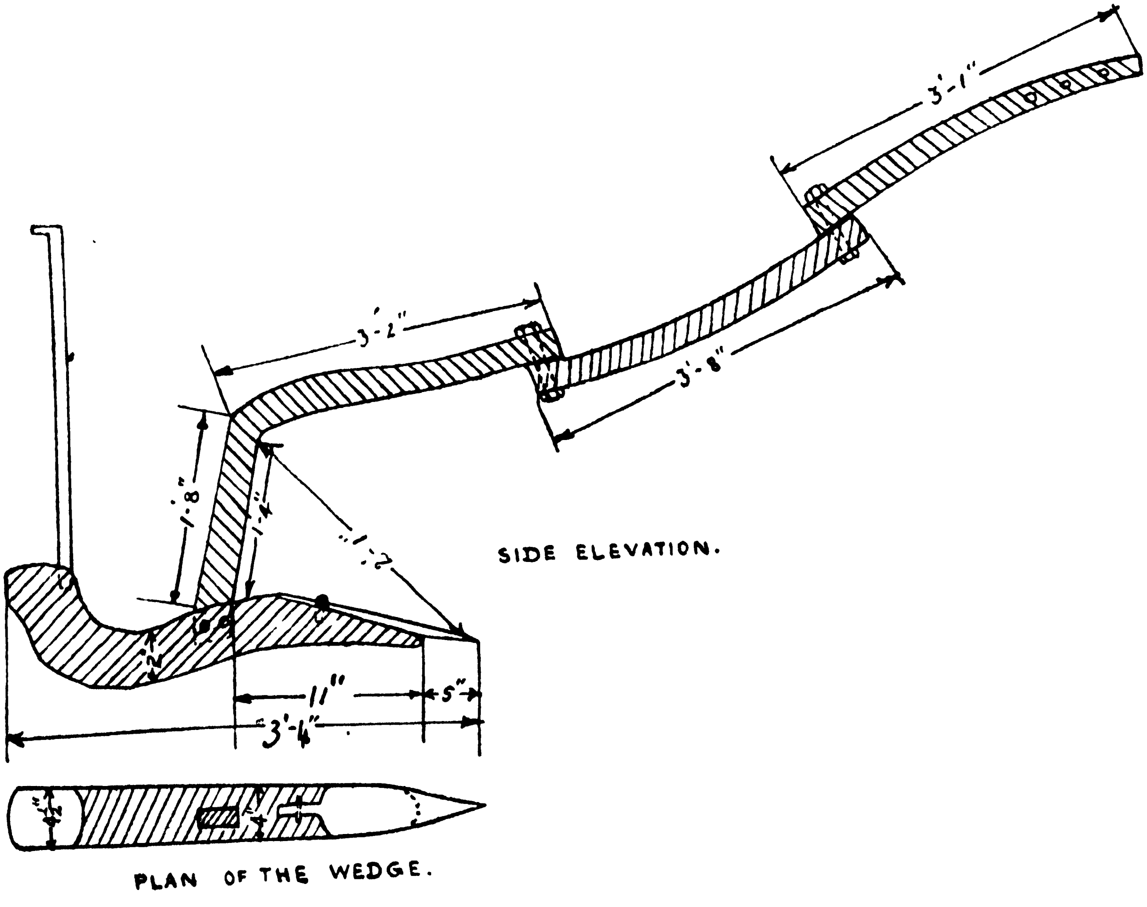


FIG. 9. Country plough, N.-W.F.P.

thickness of the body at the place where the beam is fixed to it are 6 in. and 3 in. respectively. The wedge has two shapes. Up to 14 in. from the pointed end it is a solid with a thin segmental cross-section. The flat face is protected by an iron frame and faces upwards. The remaining length of the wedge is a solid with a slight sectral cross-section, the curved surface facing downwards. The length of the wedge up to the body is 22 in. and up to its intersection with the beam is 28 in. The length of the share is 28 in. The face angle of the wedge is 31·7° and the angles which the wedge makes with the body and beam are 145° and 44·5° respectively. The weight of the plough is 51·6 lb. This plough is used in soils varying from loam to clay in Karnal district. The crops generally grown are wheat, gram, barley, *toria*, *sarson*, sugarcane, cotton, rice, maize, *jowar* and chillies. The ploughing is done after irrigation if there is no rain, the average depth of ploughing is 3 in. to 4 in. at first ploughing. It is used in both rainfed and irrigated areas. The average monthly rainfall is as follows : January = 0·59 in., February = 0·45 in., March = 0·52 in., April = 0·33 in., May = 0·63 in., June = 1·27 in., July = 4·24 in., August = 5·43 in., September = 4·78 in., October = 0·84 in., November =0·11 in., and December = 0·43 in. A pair of Hariana or Hissar bullocks with a live weight between 950 to 1148 lb., height of 4 ft. 11½ in. and with an average length 4 ft. 5 in. each is used to work this plough.

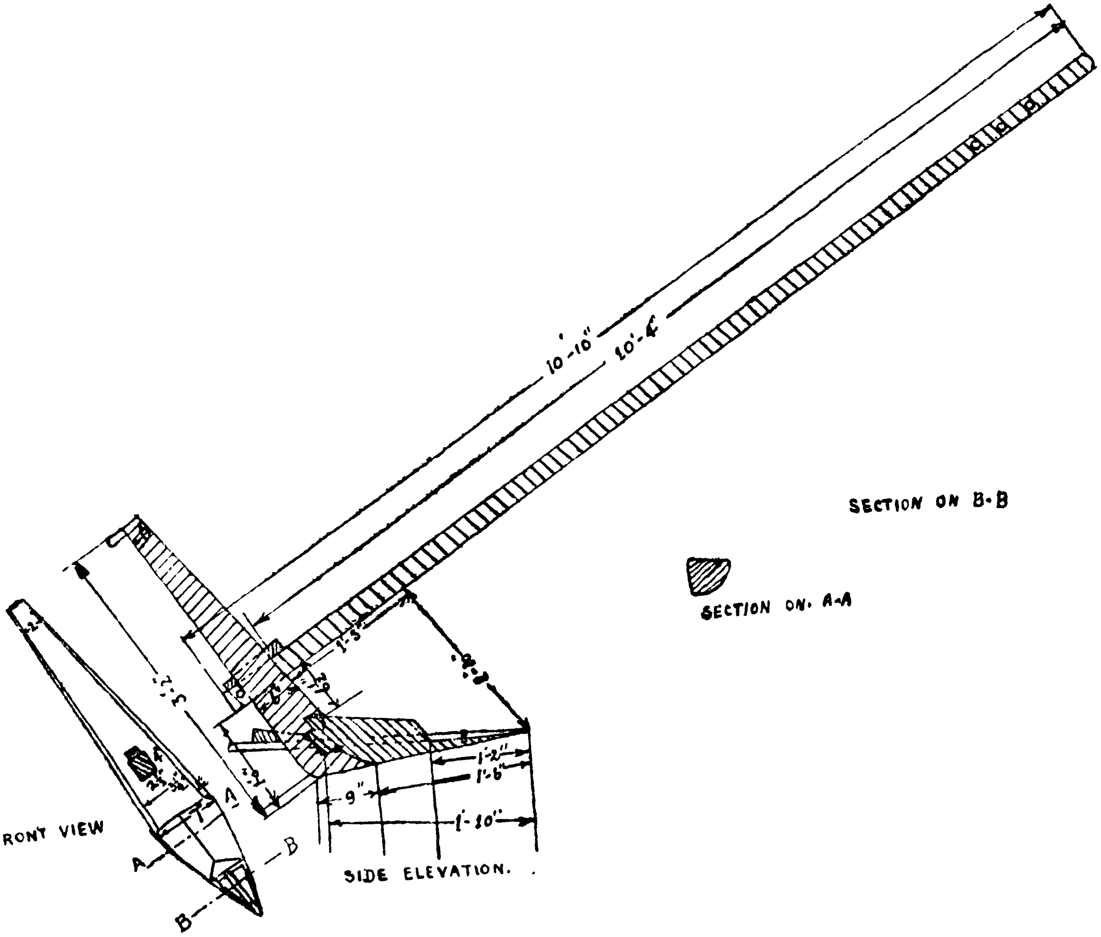


Fig. 10. Country plough, Karnal (Punjab)

(11) *Local plough, Delhi.* The dimensional diagram is given in Fig. 11. The wedge and body are made in two parts with different materials. The beam is fixed to the body at a distance of 11 in. from the place where the wedge is fixed to the body. It is of rectangular cross-section 2 in. × 4 in. and its length is 9 ft. 11 in. The body and handle are made in one piece and form a conical solid with irregular cross-sections at different places. The maximum thickness of the body just below the place where the beam is fixed to it is 5 in. The wedge is a triangular iron plate of about $\frac{3}{8}$ in. thickness with sides 7 in., 7 in. and 6 in. It is fixed to the body with the help of cotters. Its length up to its intersection with the beam is 25 in. The face angle of the wedge is 40° and the angles which the wedge makes with the body and beam are 150° and 41·3° respectively. The length of the share is 25 in. The weight of the plough is 59·7 lb. This plough is used in soils varying from sandy to clay loam and sometimes in shallow rocky soils of Delhi province. The crops generally grown are, wheat, gram, barley, *jowar*, sugarcane, cotton, pulses and vegetables. Ploughing is usually done to a depth of 2½ in. to 6 in. immediately after the first monsoon shower for *kharif* and immediately after *kharif* harvest for *rabi* season. It is used in both rainfed and irrigated tracts. The average monthly rainfall is as follows: January = 1·04 in., February = 0·76 in., March = 0·52 in., April = 0·39 in., May = 0·58 in., June = 2·99 in., July = 7·53 in., August = 7·42 in., September = 4·78 in., October = 0·32 in., November = 0·11 in., and December = 0·40 in. A pair of Hariana bullocks with a live weight of about 800 to 900 lb. each is used to work this plough.

(12) *Country plough, Aligarh* (*U. P.*) The dimensional diagram is given in Fig. 12. The

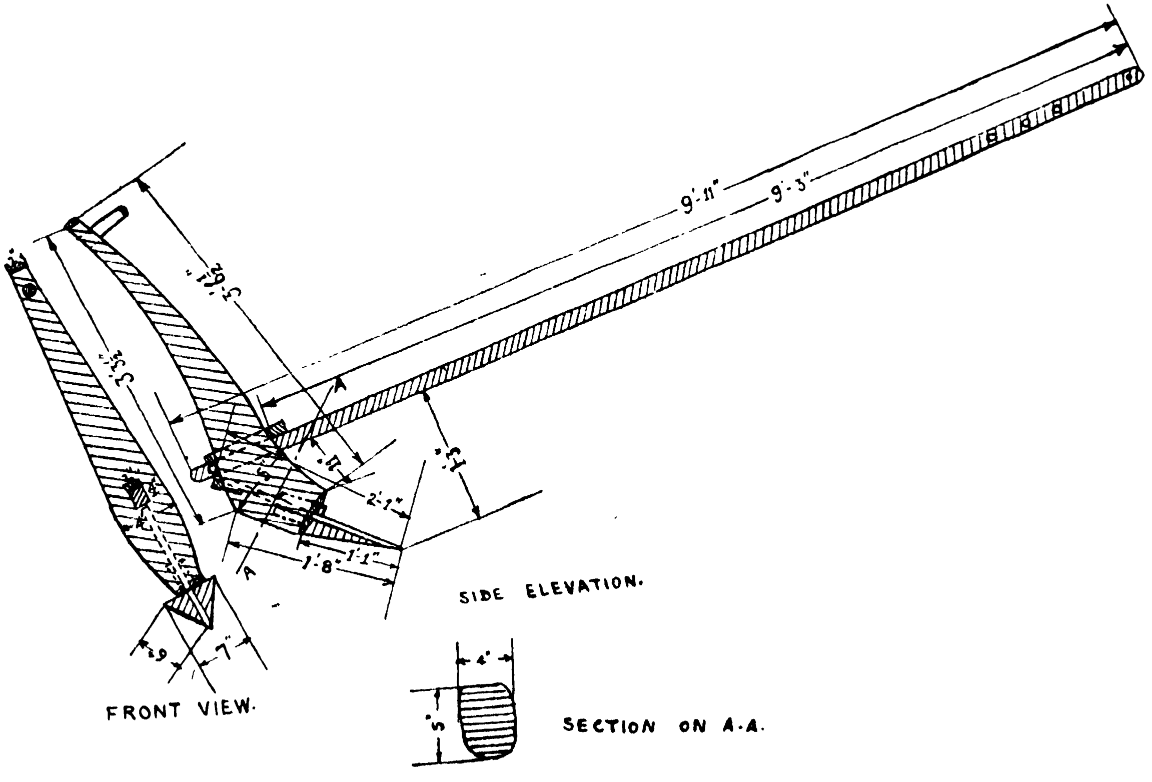


FIG. 11. Local plough, Delhi

wedge and body are made in two parts. The beam is fixed to the body at a distance of 5 in. from the inner bend between wedge and body. It is of rectangular cross-section 2 in. × 3 in. very near the body and tapers with a gradually decreasing section, its length being 9 ft. 5 in. The body and handle are made in one piece. The thickness and the width of the body at the place where the beam is fixed to it are 5 in. and 3½ in. respectively. The wedge is a pyramid of triangular cross-section having the sides at maximum section, 5 in., 5 in. and 6 in. ; and the vertex facing downwards. The length of the wedge up to the body is 18 in. and up to the intersection with the beam is 29 in. The face angle of the wedge is 16·8° and the angles which the wedge makes with body and beam are 140° and 44·4° respectively. The length of share is 10 in. The weight of the plough is 29·2 lb. This plough is used in soils varying from light to heavy loam of Aligarh and Bulandshahr districts. The crops generally grown are wheat, cotton, sugarcane, *jowar*, pulses, gram and oilseeds. Generally at the time of ploughing the soil does not contain much moisture and at times it is dry even. The depth of ploughing is usually 3 in. to 4 in. and the plough is used in both rainfed and irrigated tracts. The average monthly rainfall is as follows: January = 1·11 in., February = 0·48 in., March = 0·58 in., April = 1·14 in., May = 0·00 in., June = 1·04 in., July = 9·58 in., August = 4·06 in., September = 10·97 in., October = 0·00 in., November = 0·00 in., and December = 2·00 in. A pair of Hariana or Hissar or local bullocks with live weight 800 to 900 lb. and with a height 3 ft. 8 in. each is used to work this plough.

(13) *Country plough, Jhansi (U. P.).* The dimensional diagram is given in Fig 13. The wedge and body are made in one piece. The beam is fixed to the body at a distance of 2 in. from the inner bend. The beam is of rectangular cross-section 2 in. × 4 in. and is straight to a length of 2 ft. from the body, the remaining length being slightly curved as shown in the Fig. The total length of the beam is 7 ft. 10 in. The body is of rectangular section 4 in. × 5 in. A separate handle is fixed to the beam at the back of body. The wedge is a solid having a segmental cross-section with the curved face facing downwards. Its length up to the body is 26 in. and up to its intersection with the beam is 30 in. The face angle of the wedge is 20° and the angle which the wedge makes with the body is 145°. The length of the share is 14 in. and the weight of the plough is 44·1 lb.

(14) *Country plough, Bareilly No. 1 (U. P.)* The dimensional diagram is given in Fig. 14. This model is quite different from all the others. The wedge and body are made in two parts. The beam is fixed to the body at a distance of 6 in. from the inner bend, and is of rectangular cross-section 1½ in. × 3 in., its length being 8 ft. 9 in. The body and handle are made in one piece and the body is a trapezoidal solid. The wedge is made of a very small piece of wood, and the share which is comparatively thicker and longer acts as a wedge. The length of wedge is very small and the angles which it makes with the body and beam are 135° and 33·05° respectively. The length of the share is 18 in., and the weight of the plough is 24·2 lb. This plough is used in soils varying from sandy to loam of Bareilly district. The crops generally grown are sugarcane, paddy, maize, *jowar*, *rahar*, wheat, barley, gram, and pulses. The ploughing is done both in dry and moist conditions and to a depth of 3 in. at the first ploughing . It is used in both irrigated and rainfed tracts. The average monthly rainfall is as follows : January = 1·01 in., February = 0·92 in., March = 0·68 in., April = 0·31 in., May = 0·33 in., June = 5·14 in., July = 10·97 in., August = 12·27 in., September = 7·47 in., October = 1·19 in., November = 0·23 in., and December = 0·33 in. A pair of Ponwar bullocks with a live weight 740 to 850 lb. each is used to work this plough.

(15) *Country plough, Bareilly No. 2 (U. P.).* The dimensional diagram is given in Fig. 15. The wedge and the body are made in two pieces and the construction of this plough is similar to that of Dohad and Indore except in angles and dimensions of the parts. The beam is fixed to the body at a distance of 3 in. from the inner bend. It is of rectangular cross-section 2 in. × 2½ in., its length being 9 ft. 1 in. The body and handle are made in one piece. The wedge is very narrow and similar to that of Dohad. The length of the wedge up to the body is 22½ in. and up to its intersection with the beam is 32 in. The face angle of the wedge is 6·8° and the angles which the wedge makes with the body and beam are 140° and 40° respectively. The weight of the plough is 25·1 lb. Other conditions and particulars are similar to that of No. 14.

(16) *Country plough, Kakori (U. P.).* The dimensional diagram is given in Fig. 16. This model is very similar to that of Bareilly No. 1. Other particulars and conditions under which it is used are similar to that of Bareilly No. 1.

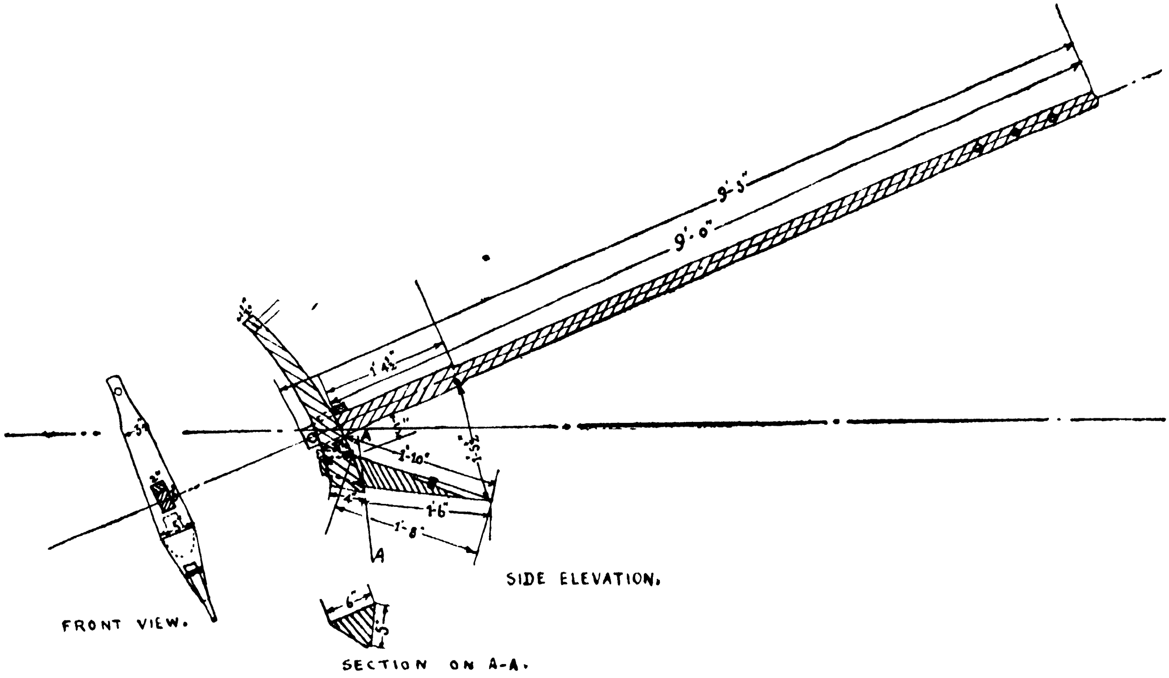


FIG. 12. Country plough, Aligarh (U.P.)

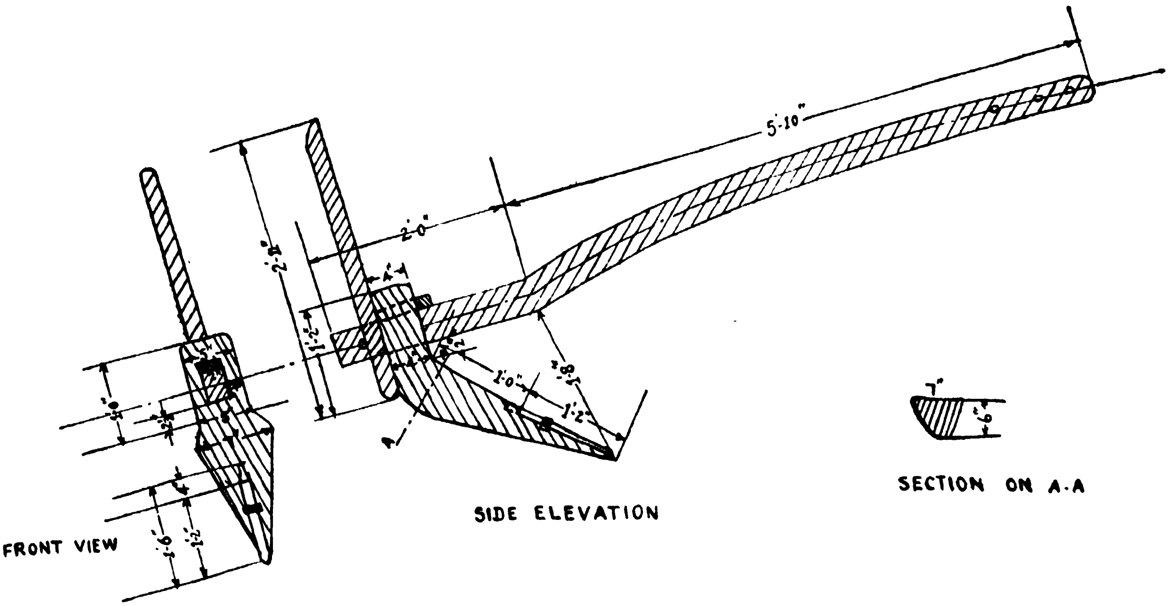


FIG. 13. Country plough, Jhansi (U.P.)

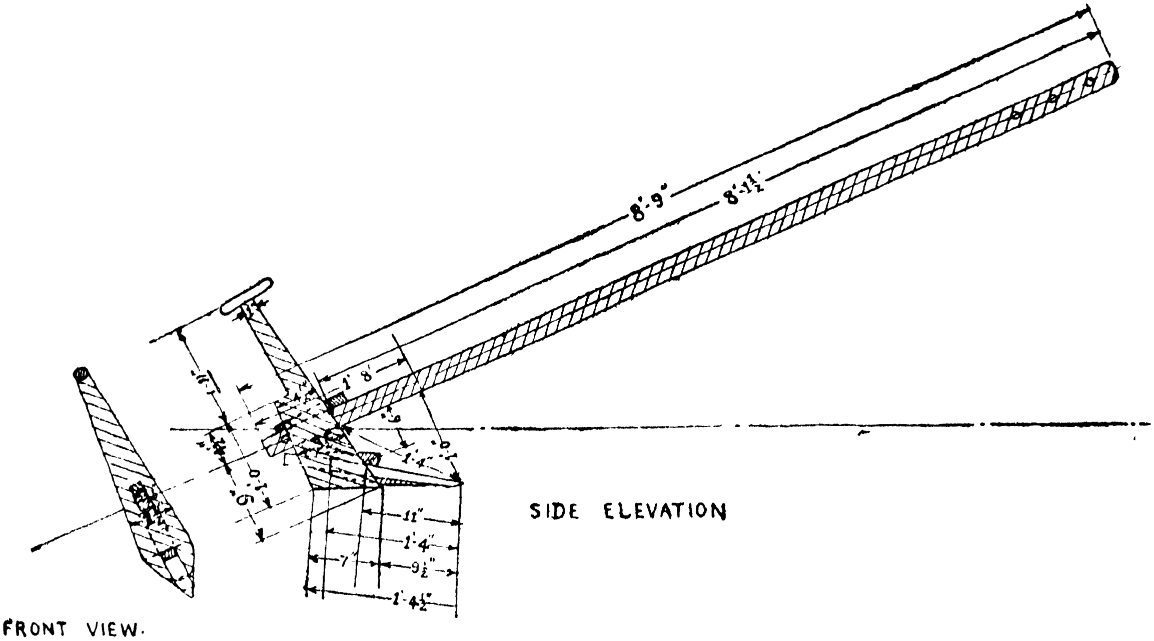


FIG. 14. Country plough, Bareilly No. 1 (U P.)

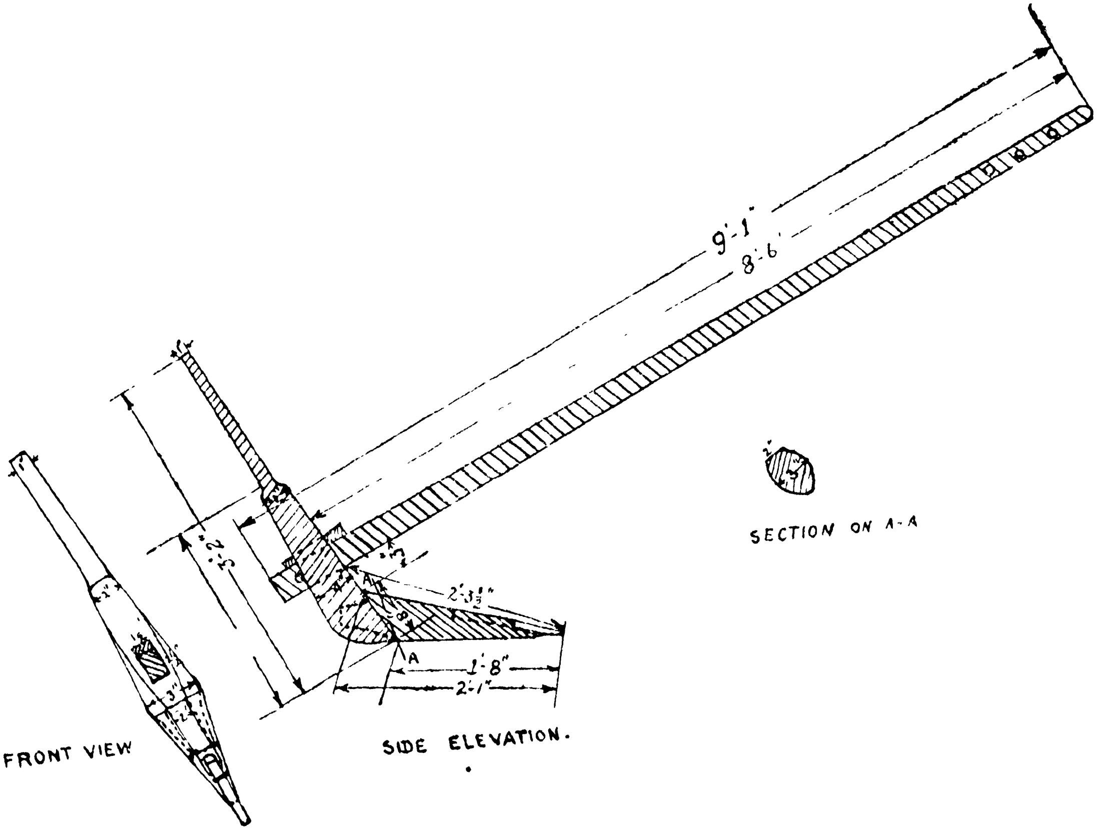


FIG. 15. Country plough, Bareilly No. 2 (U.P.)

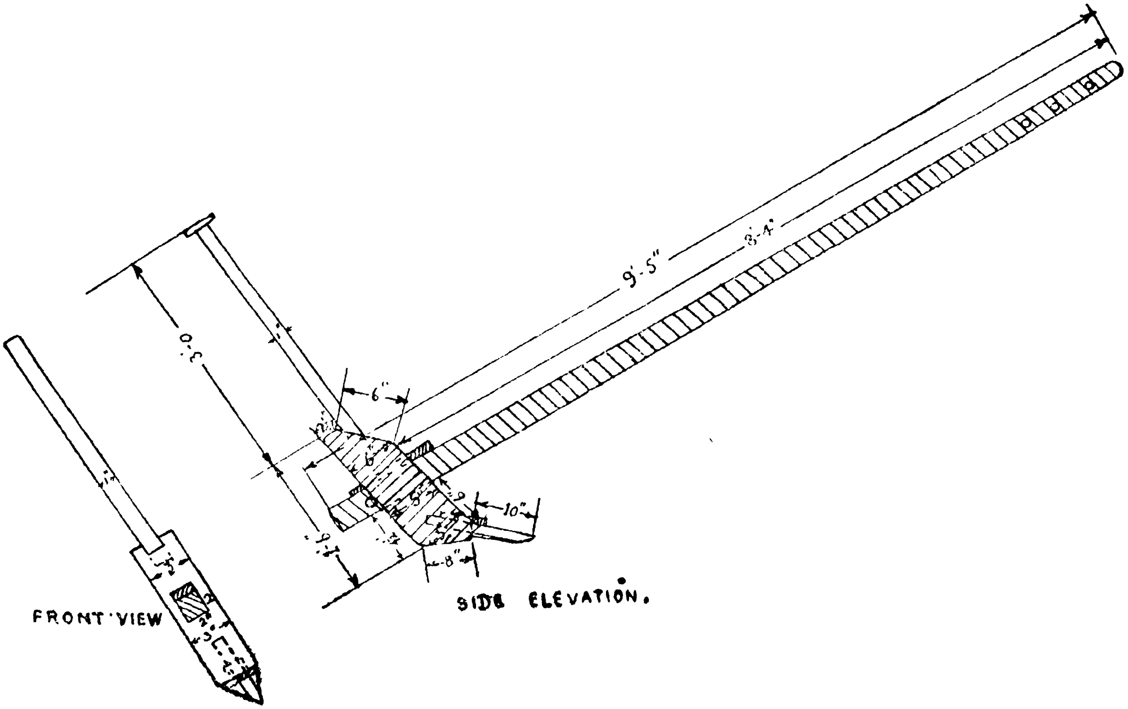


FIG. 16. Country plough, Kakori (U.P.)

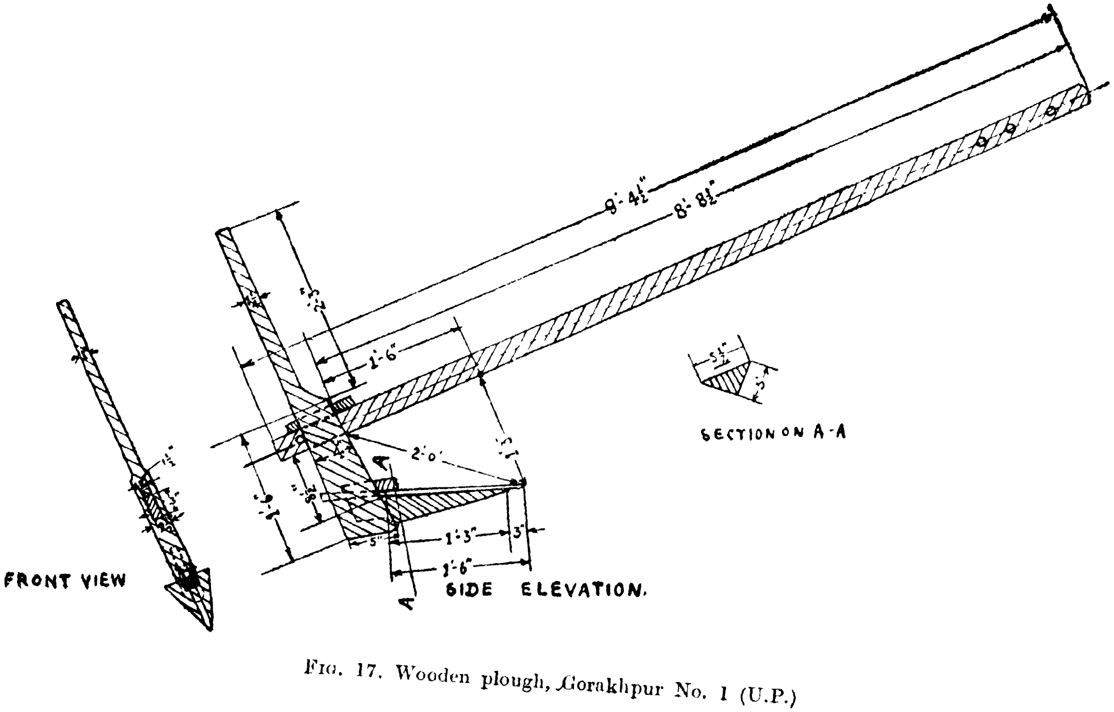


FIG. 17. Wooden plough, Gorakhpur No. 1 (U.P.)

(17) *Wooden plough, Gorakhpur No. 1* (*U. P.*) The dimensional diagram is given in Fig. 17. The wedge and body are made in two pieces. The beam is fixed to the body at a distance 8½ in. from inner bend. It is of rectangular cross-section 1½ in. × 2 in., its length being 9 ft. 4½ in. The body and handle are made in one piece and the thickness and width of the body at the place where the beam is fixed to it are 4 in. and 3 in. respectively. The wedge is a pyramid of triangular cross-section with the sides at maximum section 3 in., 3 in. and 5½ in., the vertex facing downwards and 5½ in. side facing upwards. The length of the wedge up to the body is 15 in. and up to its intersection with the beam is 28 in. The face angle of the wedge is 21·2° and the angles which it makes with the body and beam are 131° and 45° respectively. The length of the share is 24 in. The weight of the plough is 22·6 lb., and this plough is well known locally by the name *Khopidar*. This plough is used in soils varying from light sandy to heavy clay of Gorakhpur and Bahraich districts.* The crops generally grown are sugarcane, paddy, wheat, pulses, maize and oilseeds. This plough is usually used for second ploughing in heavy soils and used for all ploughings in the light soils to a depth of 6 in. to 7 in. This plough is used in both rainfed and irrigated tracts. The average monthly rainfall is as follows: January = 0·67 in., February = 0·60 in., March = 0·39 in., April = 0·40 in., May = 1·47 in., June = 7·41 in., July = 13·43 in., August = 13·99 in., September = 8·07 in., October = 3·45 in., November = 0·17 in., and December = 0·14 in. A pair of local bullocks with a live weight of 500 lb. and 3 ft. 6 in. height each is used to work this plough.

(18) Desi *plough, Gorakhpur No. 2* (*U. P.*). The dimensional diagram is given in Fig. 18. This design is similar to that of wooden plough Gorakhpur No. 1 except in the cross-section of wedge and dimensions of some parts. The wedge is a pyramid of pentagonal cross-section with sides 6½ in., ¾ in., 3 in., 3 in. and ¾ in. at maximum section, one vertex faces downwards. The length of the share is 24 in. and other particulars and conditions are similar to that of Wooden Plough No. 1.

(19) Desi *plough, Gorakhpur No. 3* (*U. P.*). The dimensional diagram is given in Fig. 19. The wedge and body are made in one piece. The beam is fixed to the body at a distance of 1 in. from the inner bend. It is of a rectangular cross-section 2 in. × 3 in., its length being 9 ft. The wedge is a pyramid of triangular cross-section having the sides 8 in., 4½ in. and 4½ in. at maximum section, with the vertex facing upwards. The length of the wedge up to the body is 21 in. and up to its intersection is 27 in. The face angle of the wedge is 23·2° and the angle which the wedge makes with the body and beam are 143° and 49·1° respectively. The length of the share is 6 in. and a separate handle is fixed to the beam at the back of the body. The weight of the plough is 23·6 lb. This plough is known locally by the name *Khutehra* (i.e. lighter) and is made of *babul* wood. It is used in clay soils of Balia and Azamgarh districts for first ploughing to a depth of 2 in. to 3 in. In other respects and conditions it is similar to No. 17.

(20) Desi *plough, Gorakhpur* (*U.P.*). This design is similar to that of No. 3, except in the length of the wedge and of weight. This plough is known locally by the name *Nauhara* and is used in Balia and Azamgarh districts.

(21) *Local plough, Chotanagpur* (*Bihar*). The dimensional diagram is given in Fig. 20. The body and the wedge are made in a single piece. There is no bend between body and wedge. The beam is fixed to the wedge and the body is of rectangular cross-section 2 in. × 3 in., its length being 9 ft. 2 in. The body is a rectangular solid with a cross-section 8 in. × 5½ in. A separate handle is fixed to it. The wedge is a frustrum of four sides with cross-section 8 in. × 5 in. × 1 in. × 5 in. at maximum section and 5½ in. × 4 in. × 1 in. × 4 in. at the penetrating end, the 1 in. side faces upwards. The wedge is chipped to form a slope at the penetrating edge. The length of the wedge is 21 in. The length of the share is 12 in. and protrudes 6 in. from the wedge. The angle which the wedge makes with the beam is 46·2°. The weight of the plough is 34·3 lb. This plough is used in soils varying from rocky to good soils of Chotanagpur. The crops generally grown are paddy, maize, *rahar*, gram, *gondli*, *marua* and cotton. The ploughing is done to a depth 1 in. to 4 in. when there is sufficient moisture which makes the soil suitable for ploughing. It is used only in rainfed areas. The average monthly rainfall is as follows: January = 0·35 in., February = 0·68 in., March = 0·41 in., April = 0·58 in., May = 1·47 in., June = 7·66 in., July = 11·48 in., August = 13·70 in., September = 8·39 in., October = 1·80 in., November = 0·41 in., and December = 0·21 in. A pair of bullocks with a live weight 650 lb., height 3 ft. 9 in. and girth 2 ft. 10 in. each or a pair of buffaloes with a live weight

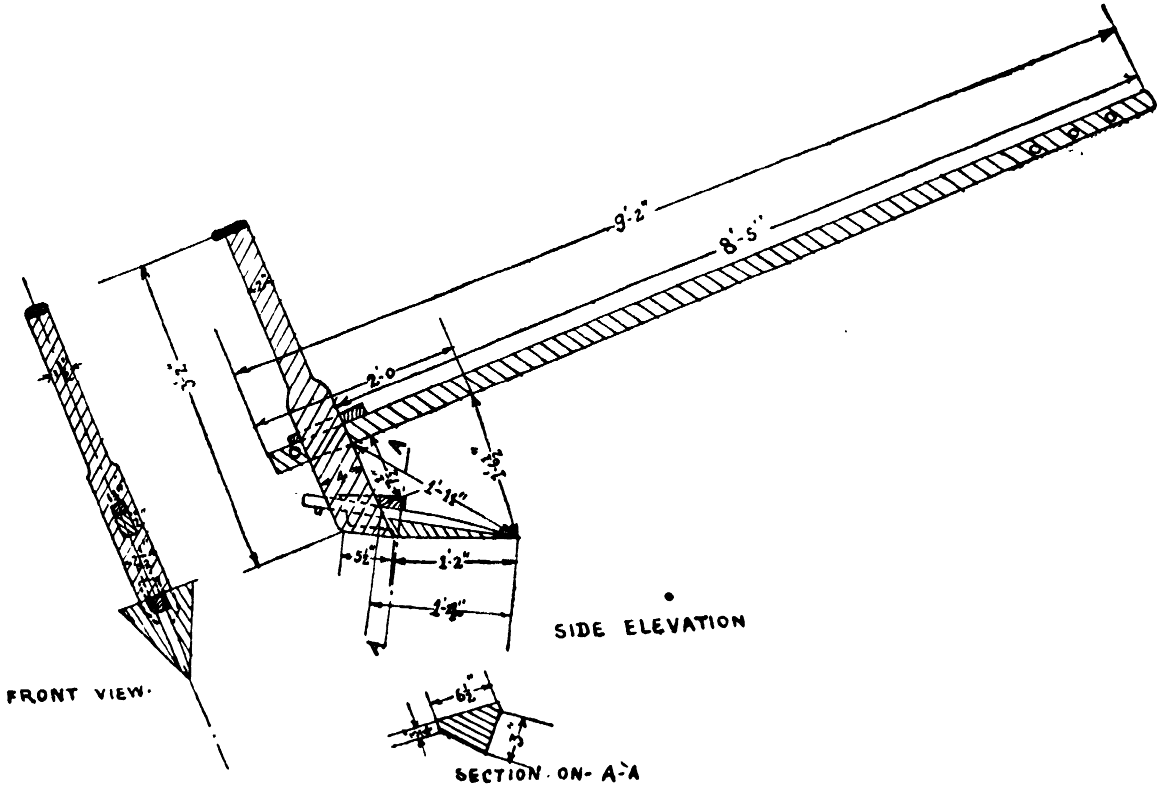


FIG. 18. *Desi* plough, Gorakhpur No. 2 (U.P.)

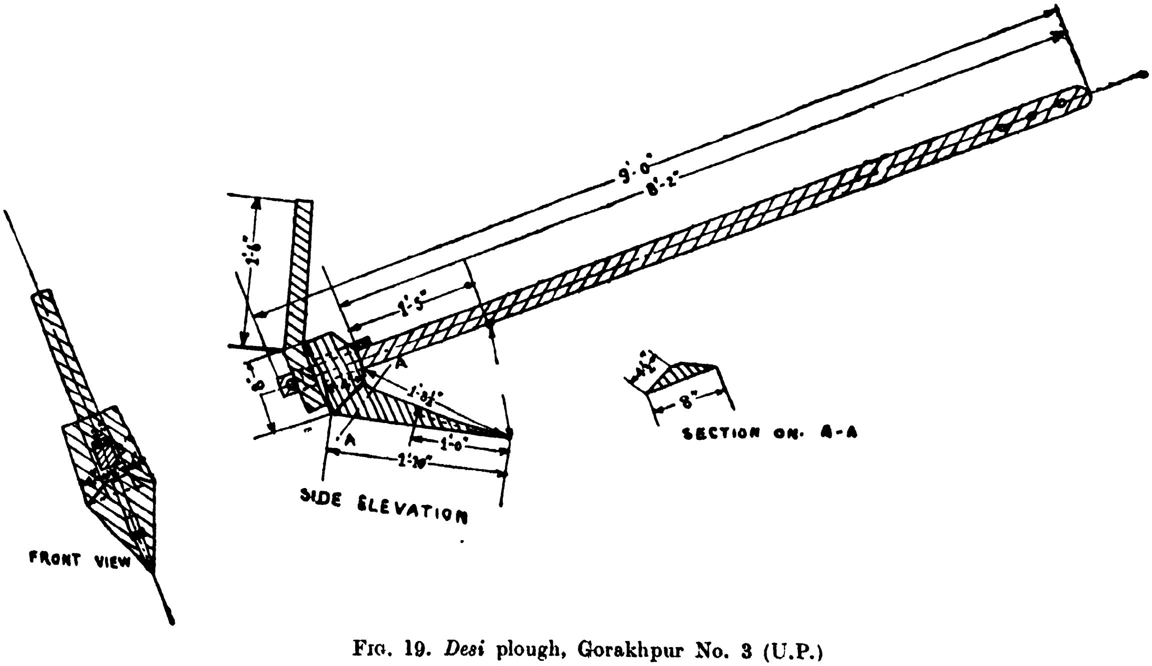


FIG. 19. *Desi* plough, Gorakhpur No. 3 (U.P.)

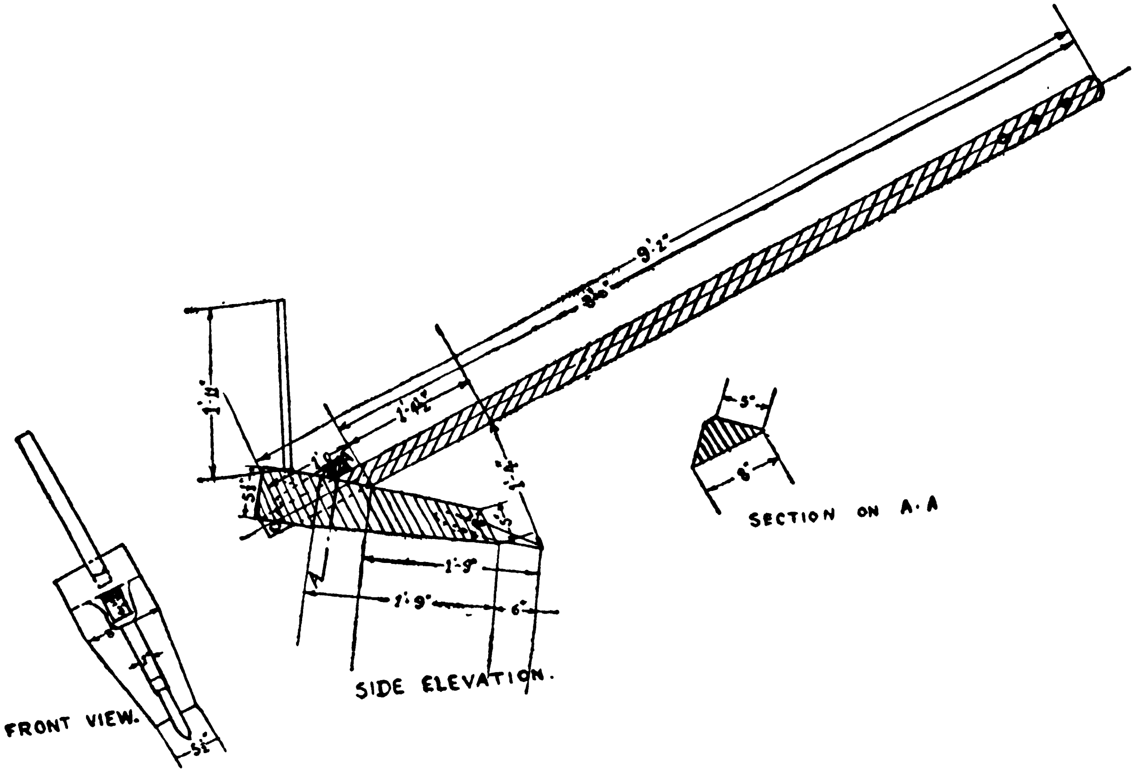


FIG. 20. Local plough, Chotanagpur (Bihar)

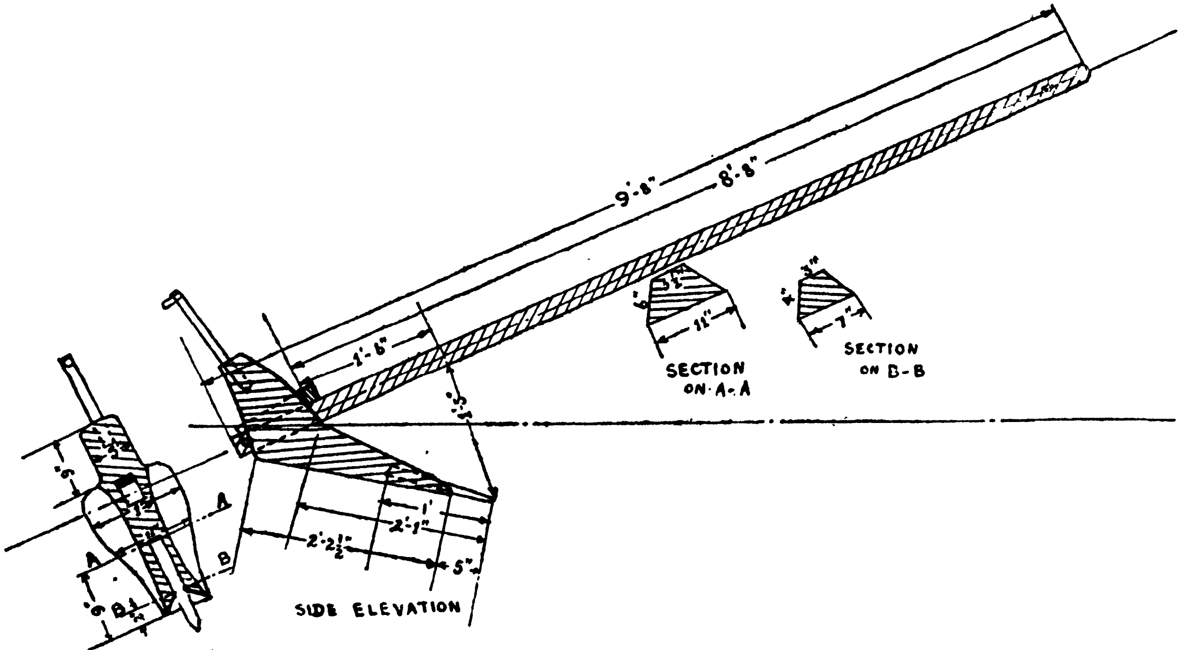


FIG. 21. Local plough, Chotanagpur, Netarhat (Bihar)

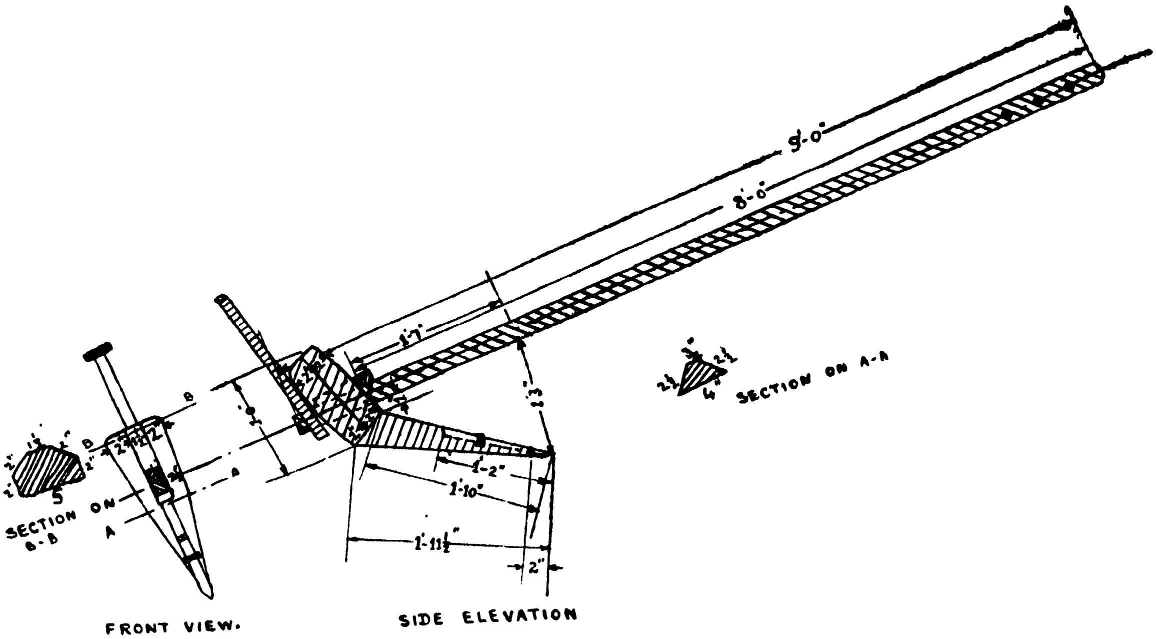


FIG. 22. Country plough, Patna (Bihar)

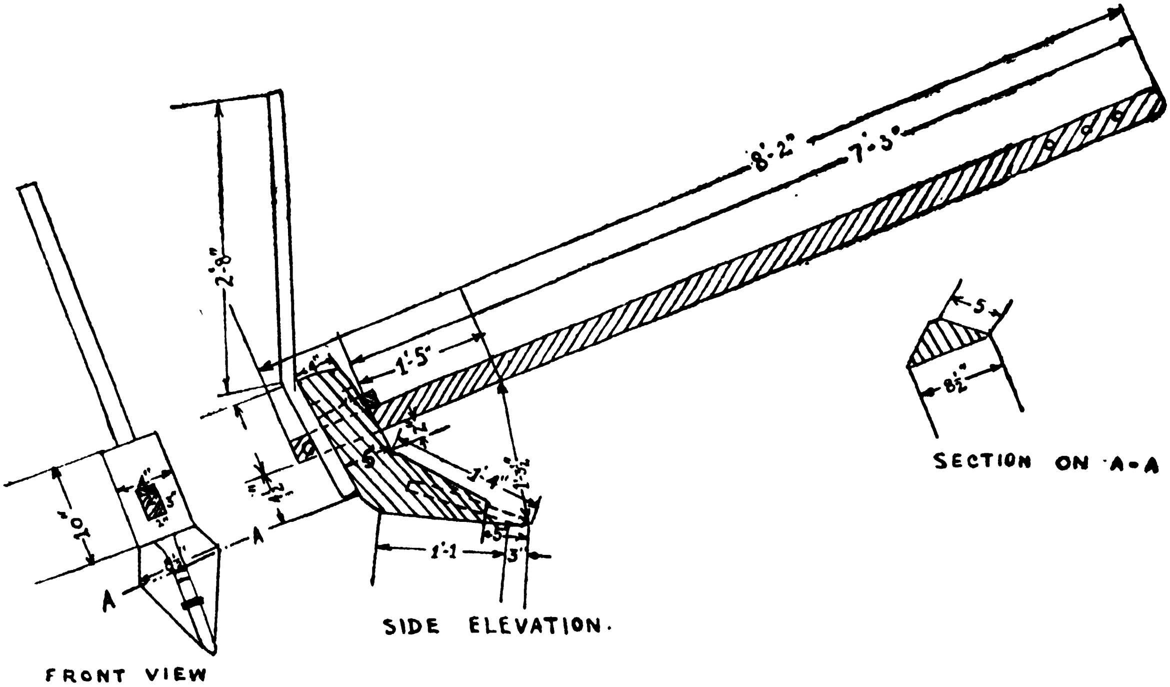


FIG. 23. Country plough, Pusa Farm (Bihar)

800 lb., height 4 ft. 4 in. and girth 3 ft. 9 in. each is used to work this plough.

(22) *Local plough, Chotanagpur, Netarhat (Bihar)*. The dimensional diagram is given in Fig. 21. This design is similar to that of L. P. Chotanagpur (21), except that there is a slight bend between the body and the wedge. The wedge and body are made in one piece and the beam is fixed to the wedge very near the bend. The beam is of rectangular cross-section 2 in. × 3 in. and its length is 9 ft. 8 in. The wedge is a solid of trapezoidal cross-section having the sides of sections 11 in., 6 in., 3½ in., 6 in. and 7 in., 4 in., 3 in., 4 in., at maximum and minimum sections respectively. The small side faces upwards. The length of the wedge up to the body is 26½ in. The angle which the wedge makes with the beam is 48·35°. A separate handle is fixed to the body. The length of the share is 12 in. and protrudes 5 in. out of the wedge. The weight of the plough is 41·8 lb. and is used in soils varying from rocky to good soils of Bishnupur and Mohwadar Thanas in Netarhat plateau. Other conditions and particulars are similar to No. 21.

(23) *Country plough, Patna (Bihar)*. The dimensional diagram is given in Fig. 22. The wedge and body are made in one piece. The beam is fixed to the body at a distance of 1 in. near the bend. It is of rectangular cross-section 1½ in. × 2½ in. and its length is 9 ft. The body is a solid of a trapezoidal cross-section and a separate handle is fixed to the beam at the back of the body. The wedge is a pyramid of triangular cross-section having the sides 6 in. × 4 in. × 4 in. at maximum section. The vertex of the section is slightly flattened and faces upwards. The length of the wedge up to the body is 22½ in. and up to its intersection with the beam is 28 in. The face angle of the wedge is 20° and the angles which the wedge makes with the body and beam are 150° and 39·5° respectively. The length of the share is 14 in. and the weight of the plough is 24·8 lb. This plough is used in all kinds of soils in Patna district. The crops generally grown are paddy, *rahar*, sugarcane, wheat, gram, etc. The ploughing is done to a depth of 3 in. when the moisture is about 15 per cent. It is used in both rainfed and irrigated tracts and the average monthly rainfall is as follows: January = 0·53 in., February = 0·71 in., March = 0·47 in., April = 0·30 in., May = 1·67 in., June = 8·12 in., July = 11·94 in., August = 13·55 in., September = 8·33 in., October = 2·54 in., November = 0·28 in., and December = 0·09 in. A pair of country bullocks with a live weight 500 lb. each is used to work this plough.

(24) *Country plough, Pusa (Bihar)*. The dimensional diagram of this plough is given in Fig. 23. The wedge and body are made in one piece and the beam is fixed to the body at a distance of 2 in. from the inner bend. The beam is of a rectangular cross-section 2 in. × 3 in. and its length is 8 ft. 2 in. The thickness and the width of the body at the place where the beam is fixed to it are 5 in. and 4 in. respectively. A separate handle is fixed to the beam at the back of the body. The wedge is a pyramid of triangular cross-section with the vertex slightly flattened and facing upwards. The sides of cross-section at maximum section are 8½ in., 5 in. and 5 in. The length of the wedge up to the body is 16 in. and up to its intersection with the beam is 22 in. The face angle of the wedge is 35° and the angles which the wedge makes with the body and the beam are 150° and 44·9° respectively. The length of share is 12 in. and protrudes 2 in. outside the wedge. The weight of the plough is 34·3 lb. This plough is used in soils varying from sandy to heavy loams of Muzaffarpur, Darbhanga, Saran and South Champaran districts. The crops generally grown are sugarcane, wheat, barley, maize, *rahar*, pulses and paddy. The ploughing is done to a depth of 3 in. when the moisture is about 20 per cent and the plough is used for puddling paddy fields. It is used mostly in rainfed areas and the average monthly rainfall is as follows: January = 0·35 in., February = 0·68 in., March =0·41 in., April = 0·58 in., May = 1·47 in., June =7·66 in., July = 11·48 in., August = 13·70 in., September = 8·39 in., October = 1·80 in., November = 0·41 in., and December = 0·21 in. A pair of local bullocks with live weight 600 to 800 lb. each is used to work this plough.

(25) *Local plough, Chotanagpur, Ranchi (Bihar)*. The dimensional diagram is given in Fig. 24. The wedge, the body and the handle are made in one piece. The beam is fixed to the body at a distance of 3 in. from the inner bend and is of rectangular section 2 in. × 3 in., its length being 6 ft. 7 in. The body is a solid trapezium in cross-section. The wedge is a pyramid of triangular cross-section having the sides 5½ in., 3 in. and 3 in. at maximum section with its vertex slightly flattened and facing upwards. The face angle of the wedge is 28° and the angles which the wedge makes with the body and beam are 150° and 39·05° respectively.

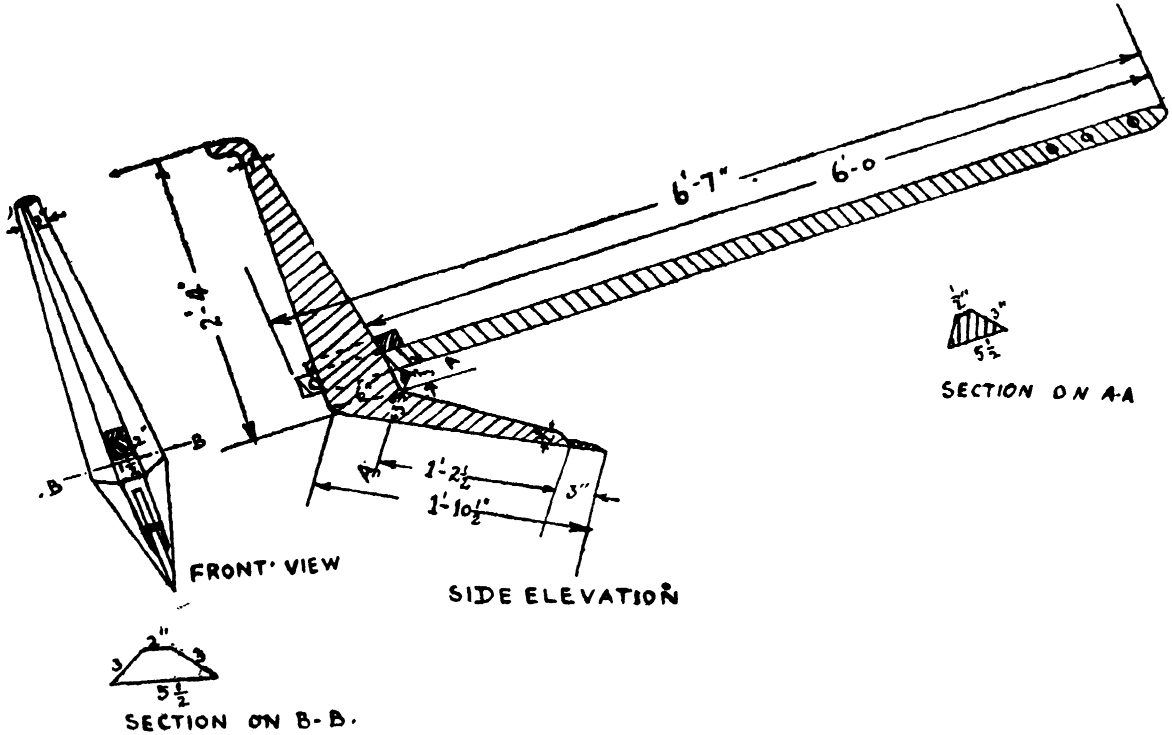


Fig. 24. Local plough, Chotanagpur, Ranchi (Bihar)

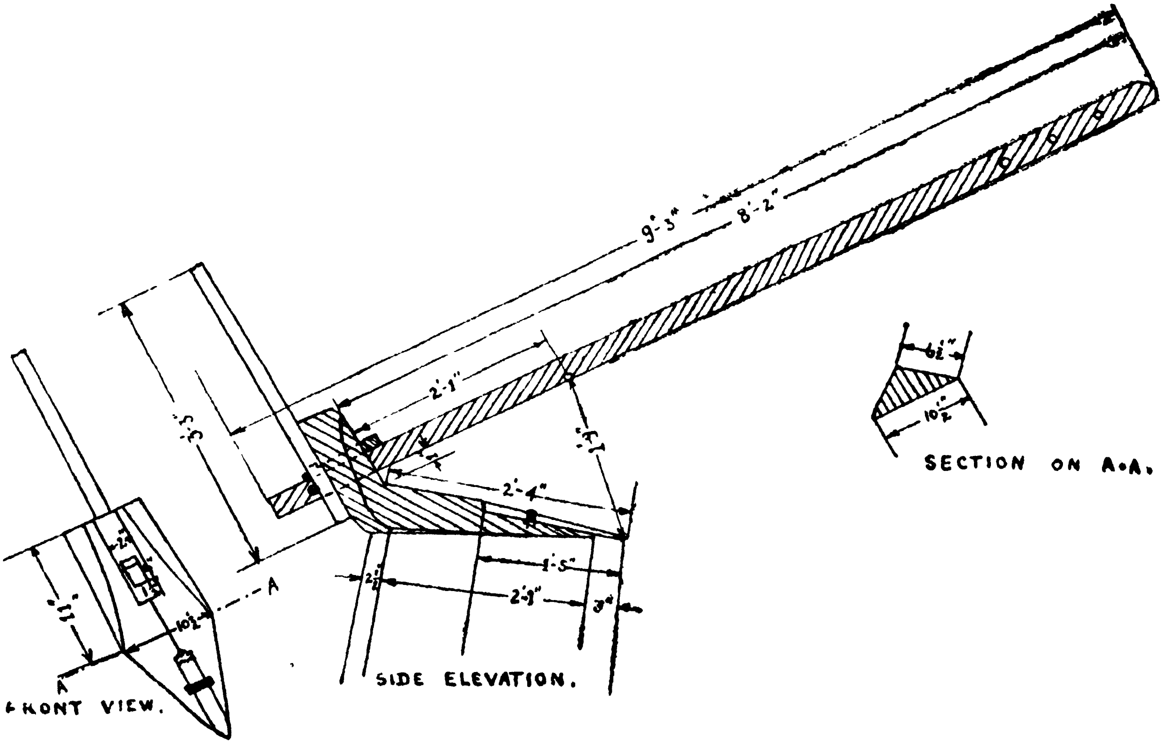


Fig. 25. Native plough, Sabour (Bihar)

The length of the wedge up to the body is 22½ in. and up to the beam is 28 in. The length of the share is 16 in. and projects 3 in. outside the wedge; and the weight of the plough is 16·4 lb. This plough is used in the soils varying from sandy loam with grit in the uplands to heavy clay in the valley or dune of Ranchi district. The crops grown generally are paddy, *rahar*, maize, pulses, barley and wheat. Ploughing is usually done after rains when the moisture is between 25 per cent to 30 per cent. In the first instance the depth of the ploughing is between 1½ in. to 3 in. and the second ploughing it is 2½ in. to 3 in. It is used in rainfed areas and the average monthly rainfall is as follows: January = 0·79 in., February = 1·60 in, March = 1·30 in., April = 0·95 in., May = 2·41 in., June = 9·68 in., July = 14·77 in., August = 13·17 in., September = 9·14 in., October = 2·84 in., November = 0·38 in., and December = 0·18 in. A pair of bullocks with live weight 330 to 410 lb. each or buffaloes with live weight 650 to 900 lb. each is used to work this plough.

(26) *Native plough, Sabour* (*Bihar*). The dimensional diagram is given in Fig. 25. The wedge and body are made in one piece. The beam is fixed to the body at a distance of 2 in. from the inner bend and is of rectangular section 1½ in. × 3 in., its length being 9 ft. 3 in. A separate handle is fixed to the beam at the back of the body. The wedge is a triangular pyramid having the sides of cross-section at its maximum 10½ in., 6½ in. and 6½ in. with the vertex facing upwards. The length of the wedge up to the body is 28 in. and up to its intersection with the beam 37 in. The face angle of the wedge is 30° and the angles which the wedge makes with body and beam are 155° and 45·5° respectively. The length of the share is 17 in. and it is thick and broad. The weight is 44·1 lb. and the plough is used in soils varying from light to heavy of Bhagalpur district and ploughing is done when the moisture percentage is very high. For puddling purpose the wedge will be made a bit narrow. In Santhal Parganas the same plough with narrow wedge is used as the animals are comparatively weak and small. The crops generally grown are paddy, maize and pulses. Ploughing is done usually to a depth of 3 in. to 4 in It is used in rainfed areas and the average monthly rainfall is as follows: January = 0·41 in., February = 0·72 in., March = 0·37 in., April = 0·67 in., May = 3·51 in., June = 7·90 in., July = 11·13 in., August = 11·54 in., September = 8·83 in., October = 2·45 in, November = 0·33 in., and December = 0·08 in. A pair of local bullocks or buffaloes is used to work this plough.

(27) *Wooden country plough, Bankura* (*Bengal*). The dimensional diagram is given in Fig. 26. The body and wedge are made in one piece. The beam is fixed to the body at a distance of 3 in. from the inner bend between the body and wedge. It is of rectangular section 2 in. × 4 in. up to 2 ft. from the body and oval in the remaining length and its length being 8 ft. 5 in. A separate handle is fixed to the body. The wedge is a pyramid of triangular cross-section with sides 9½ in., 4 in. and 4 in. and with its vertex facing upwards. The length of the wedge up to the body is 20½ in. and up to its intersection with the beam is 28 in. The face angle of the wedge is 39° and the angles which the wedge makes with the body and beam are 135° and 41·9° respectively. A flat share is used to protect the penetrating edge. The weight of the plough is 31 lb. This plough is used in sedulary laterite soils, with full gravels of various sizes of Bankura district. Paddy is the only crop grown in this district. Ploughing is usully done to a depth from 3 in. to 4 in. It is used in waterlogged condition or when the moisture percentage is high. It is used in both rainfed and irrigated areas. The average rainfall is as follows: January = 0·19 in., February = 1·66 in., March = 0·76 in., April = 0·97 in., May = 2·77 in., June = 8·68 in., July = 11·62 in., August = 11·52 in., September = 7·01 in., October = 2·52 in, November = 0·39 in., and December = 0·12 in A pair of bullocks with live weight of 170 lb. each is used to work this plough.

(28) *Wooden plough, Tippera* (*Bengal*). The dimensional diagram is given in Fig. 27. The body and the wedge are made in one piece. The beam is fixed to the body very near the inner bend and is of rectangular cross-section 1½ in. × 2½ in. and its length being 7 ft. 3 in. A separate handle is fixed to the beam in front of the body. The cross-section of the wedge is shown in the diagram. It will be seen that the vertex faces upwards. The length of the wedge up to the body is 23 in. and up to its intersection with the beam is 25 in. The angles which the wedge makes with the body and the beam are 130° and 40° respectively. The weight of the plough is 28 lb. This plough is used in new alluvial soil of light texture—Meghna silt in Tippera district. The crops generally grown are paddy, jute and pulses. Ploughing is usually done to a depth of 3 in. to 4 in. when the moisture is about 15 per cent to 25 per cent. It is

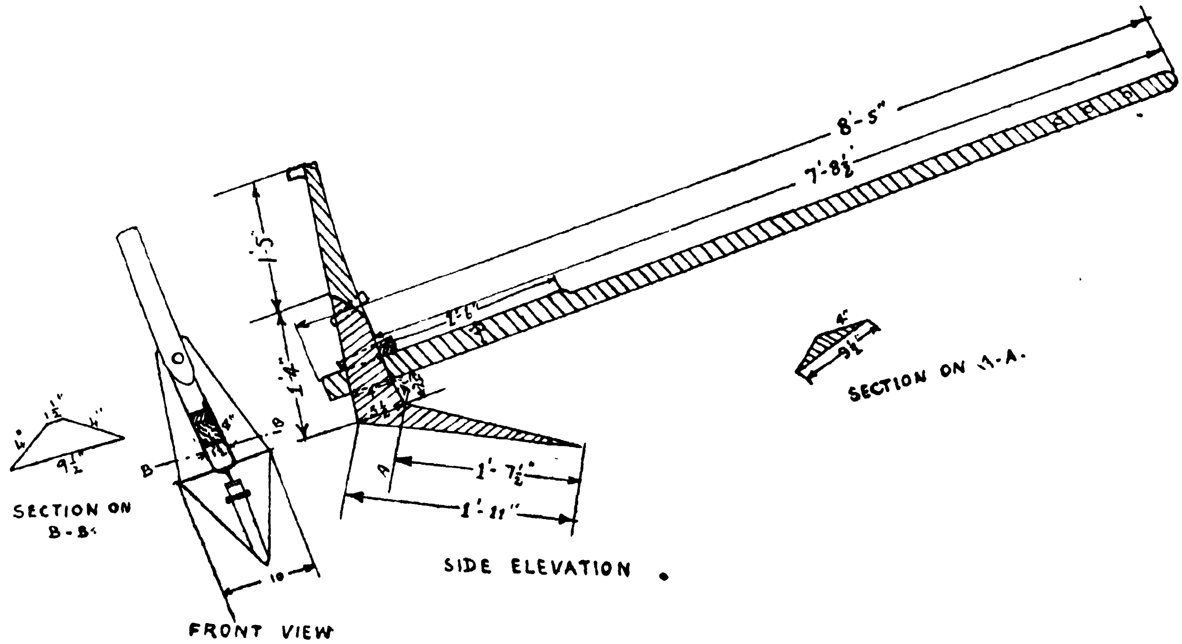


FIG. 26. Country plough, Bankura (Bengal)

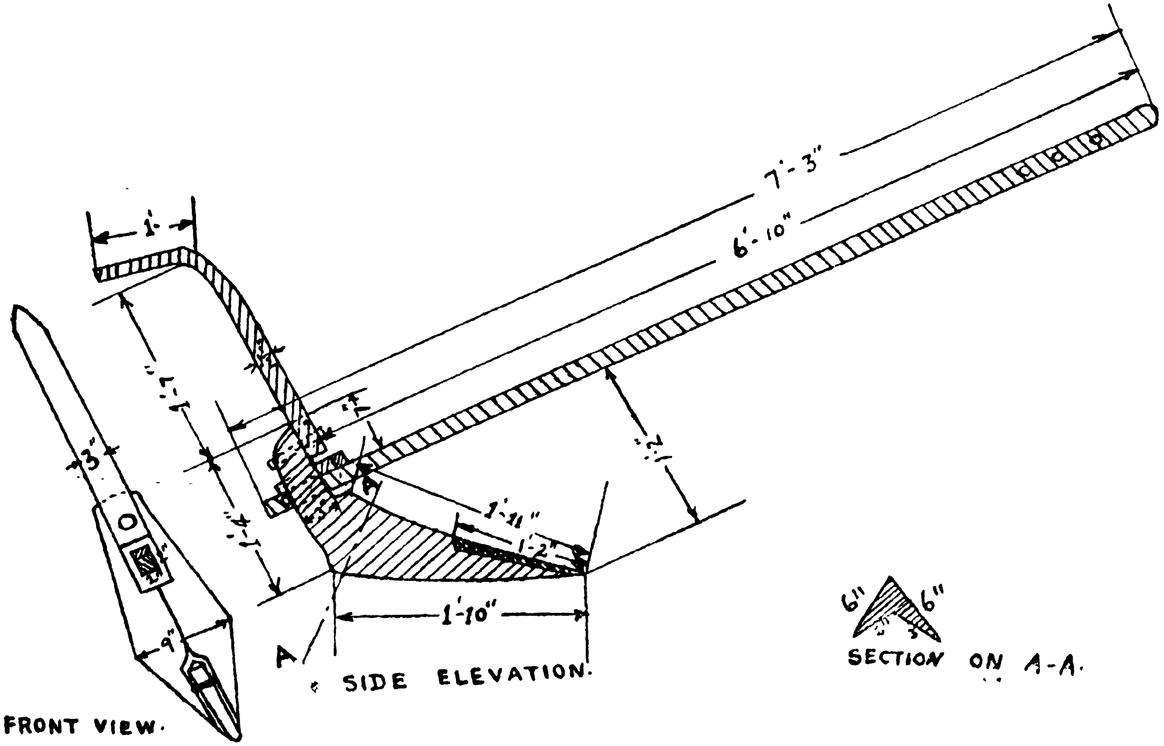


FIG. 27. Wooden plough, Tipperah (Bengal)

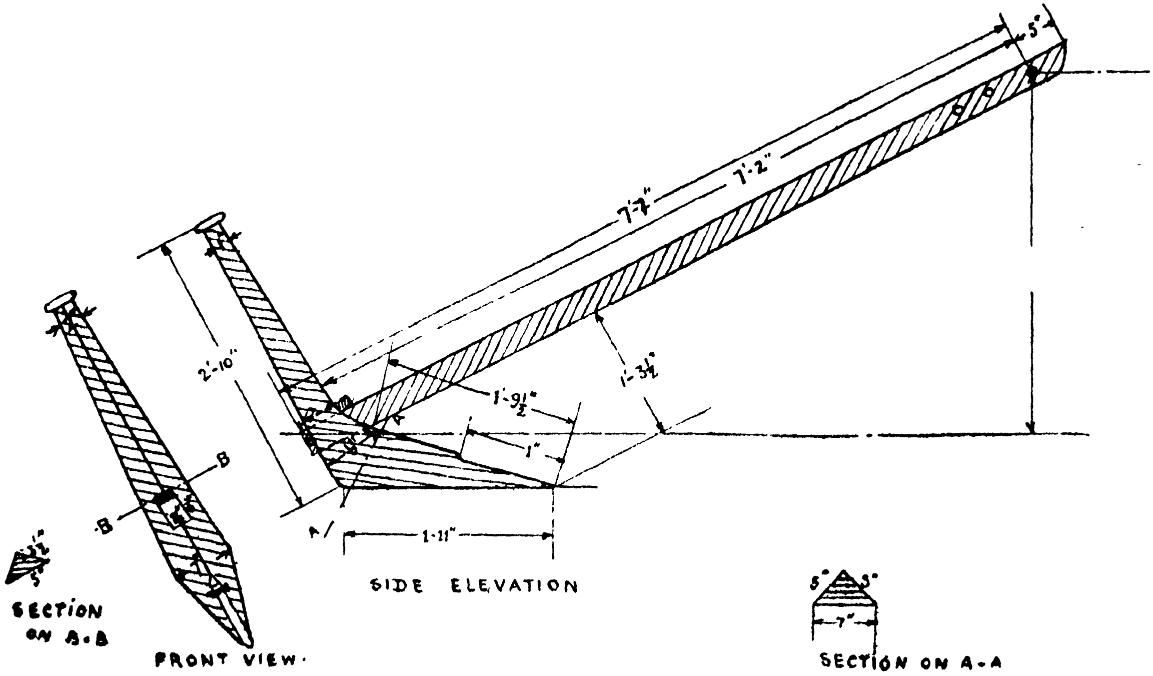


Fig. 28. Country plough, Rangpur (Bengal)

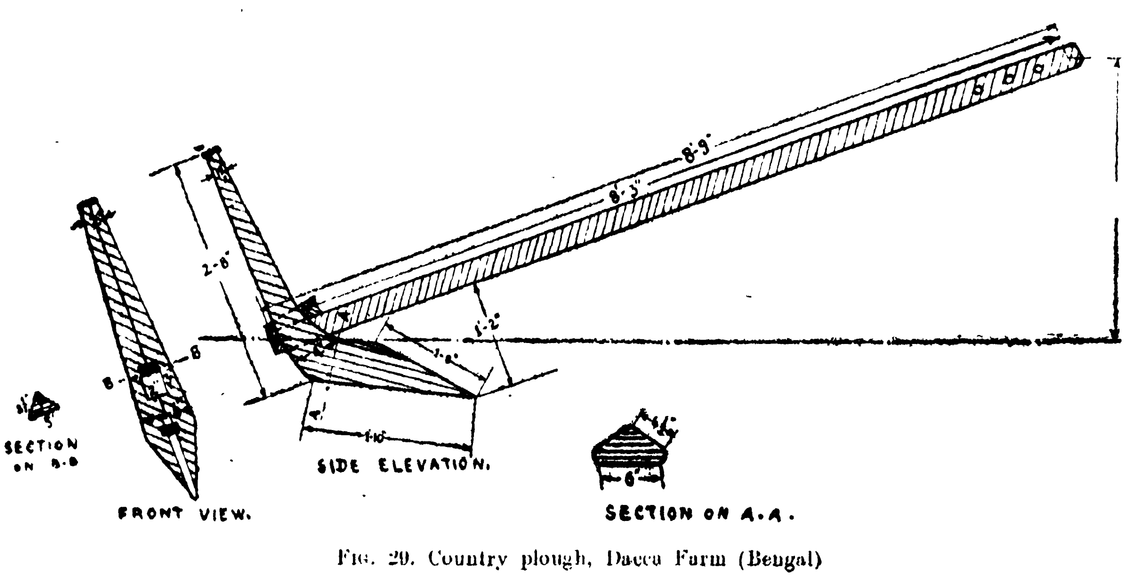


Fig. 29. Country plough, Dacca Farm (Bengal)

used in rainfed areas only and the average rainfall is as follows: January = 0·29 in., February = 1·08 in., March = 2·95 in., April = 6·58 in., May = 11·77 in., June = 18·05 in., July = 15·05 in. August = 14·91 in., September = 10·93 in., October = 6·52 in., November = 1·03 in., and December = 0·23 in. A pair of local bullocks with a live weight 500 lb. each is used to work this plough.

(29) *Country plough, Rangpur* (*Bengal*). The dimensional diagram is given in Fig. 28. The wedge, the body and the handle are made in one piece. The beam is fixed to the body very near the inner bend and is of rectangular cross-section 1½ in. × 3 in., its length being 7 ft. 7 in. The body is a solid of triangular cross-section. The wedge is a pyramid of triangular cross-section with sides 7 in., 5 in., and 5 in. and with vertex facing upwards. The length of the wedge up to the body is 21½ in. and up to its intersection with the beam is 24 in. The face angle of the wedge is 19·2° and the angles which the wedge makes with the body and beam are 138° and 46·2° respectively. A small share is used in this plough. The weight of the plough is 20 lb. This plough is used in new alluvial soil with light texture of sandy Tista silt of Rangpur district. The crops generally grown are mostly transplanted paddy and jute. Ploughing is usually done to a depth of 3 in. to 4 in. when the moisture is between 15 to 20 per cent. It is used mostly in rainfed areas and the average rain is as follows: January = 0·06 in., February = 1·27 in., March = 0·41 in., April = 1·92 in., May = 14·72 in., June = 14·69 in., July 19·35 in., August = 17·59 in., September = 11·20 in., October = 5·23 in., November = 0·11 in, and December = 0·23 in. A pair of local bullocks with a live weight 470 lb. each is used to work this plough.

(30) *Country plough, Dacca Farm* (*Bengal*). The dimensional diagram is given in Fig. 29. The body wedge and handle are made in one piece. The beam is of rectangular cross section 2 in. × 3 in. and its length is 8 ft. 9 in. The body is a solid of triangular cross-section and the design of the plough is similar to that of Rangpur. The wedge is a pyramid of triangular cross-section, with its edges slightly curved. The sides of cross-section at maximum section are 6 in., 4 in. and 4 in. and the vertex facing upwards. Part of the vertex near the penetrating point is considerably flattened to fix the share. The vertex facing upwards is straight up to maximum section which is at a distance of 20 in. from the penetrating points of the wedge and afterwards it is curved. The length of the wedge up to the outer bend is 22 in. and up to its intersection with the beam is 24 in. The face angle of the wedge is 14° and the angles which the wedge makes with the body and beam are 135° and 45·6° respectively. The length of the share is 12 in. and the weight of the plough is 23·9 lb. This plough is used in red soils of heavy texture, old and new alluvial soils with light texture of Dacca district. The crops generally grown are paddy (transplanted and broadcast too), jute, pulses, wheat and barley. Ploughing is done to a depth of 3 in. to 4 in. when the moisture is about 15 to 20 per cent and the plough is used under waterlogged condition. The plough is used mostly in rainfed areas and the average rainfall is as follows: January = 0·17 in., February = 1·89 in., March = 0·97 in., April = 3·09 in., May = 12·97 in., June = 15·17 in., July = 10·26 in., August = 15·47 in., September = 7·59 in., October = 3·15 in., November = 0·46 in., and December = 0·34 in. A pair of local bullocks with a live weight of 500 lb. each is used to work this plough.

(31) *Orissa plough, Potangi* (*Orissa*). The dimensional diagram is given in Fig. 30. This design is absolutely different from the others. There is no bend between body and wedge and hence we can say that the wedge itself acts as body also. The beam is directly fixed to the wedge at a distance of 18 in. from the pointed end. The beam is of circular cross-section and is bent at the end where it is fixed to the wedge, and is straight for the remaining length. The total length of the beam is 8 ft. A separate curved wood piece is used as handle and is fixed to the wedge at the back of the beam. The wedge is a solid cone and its solid angle is 5°. The length of the wedge is 30 in. and maximum diameter of the cone is 2½ in. The wedge is slightly chipped at the pointed end and a share of 6 in. length used. The weight of the plough is 19·2 lb. Angle between the wedge and the beam is 40°.

(32) *Orissa plough, Udayagiri* (*Orissa*). The dimensional diagram is given in Fig. 31. The wedge, body and handle are made in one piece. The beam is fixed to the body at a distance of 2 in. from the inner bend and is circular in cross section with 3 in. diameter. Its length is 7 ft. 6 in. The wedge is a pyramid with pentagonal cross-section with sides 5½ in., 1½ in., 3½ in., 3½ in and 1½ in. at maximum section and the vertex facing upwards. The face angle of the wedge is

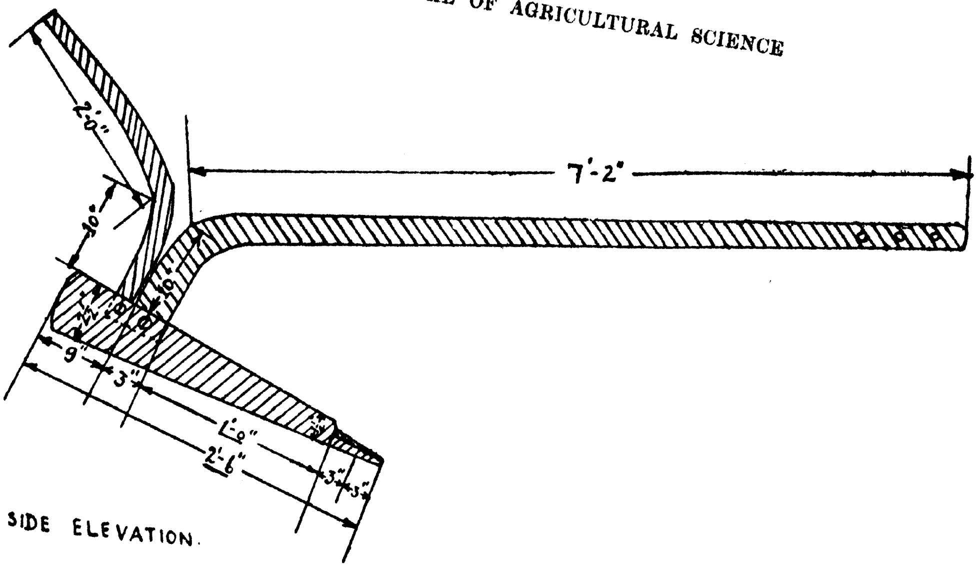


Fig. 30. Orissa plough, Potangi (Orissa)

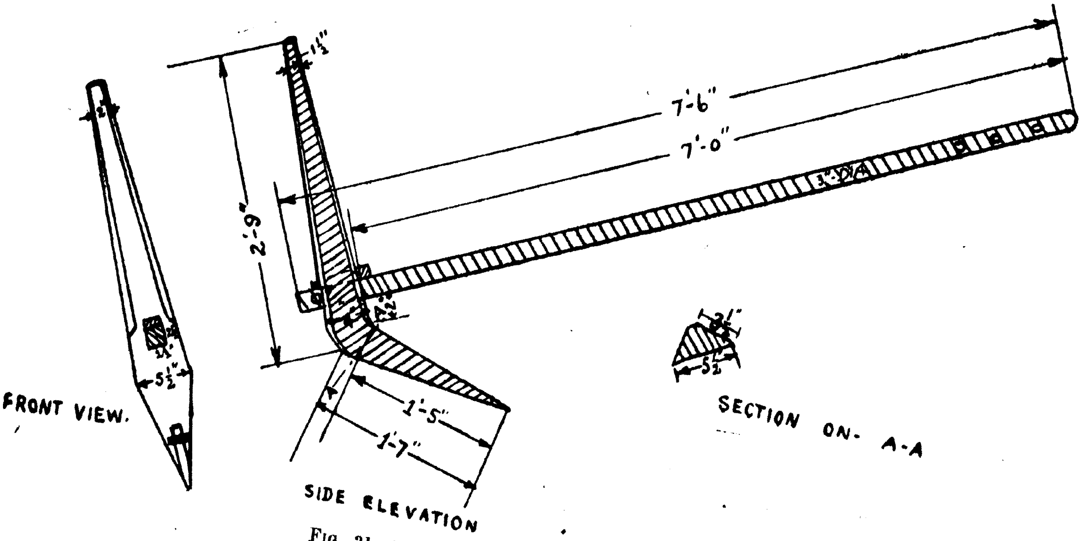


Fig. 31. Orissa plough, Udayagiri (Orissa)

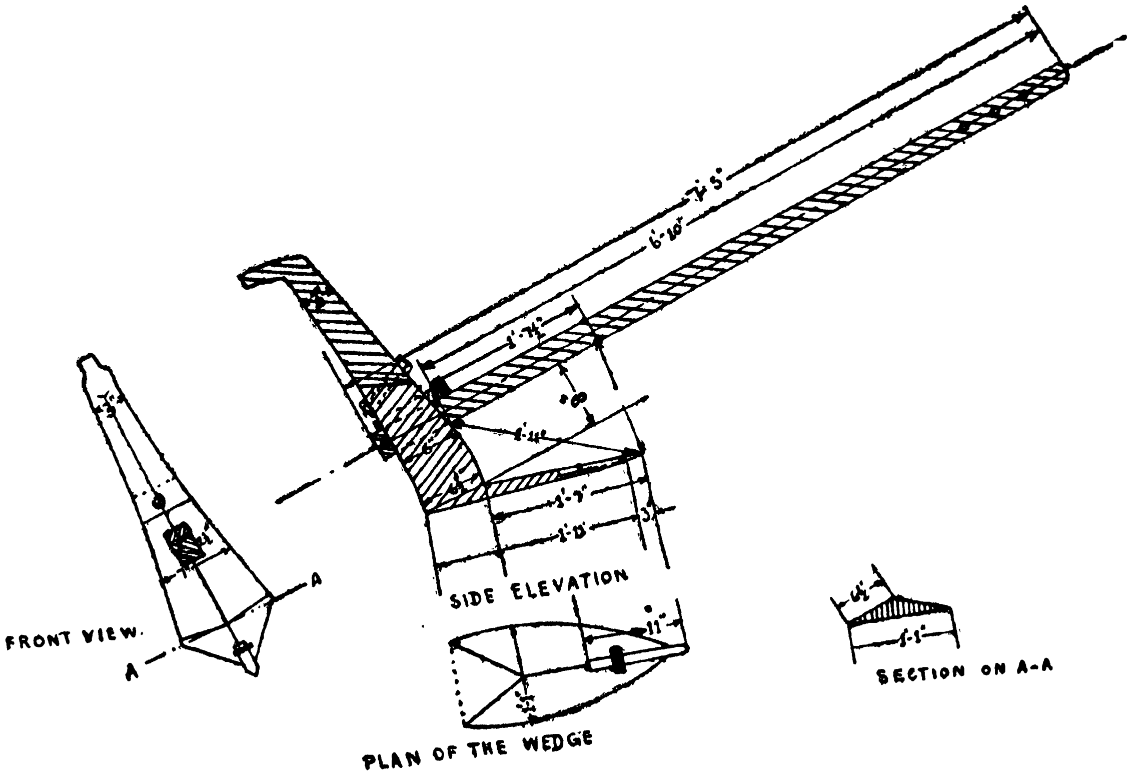


Fig. 32. Country plough, Sambalpur (Orissa)

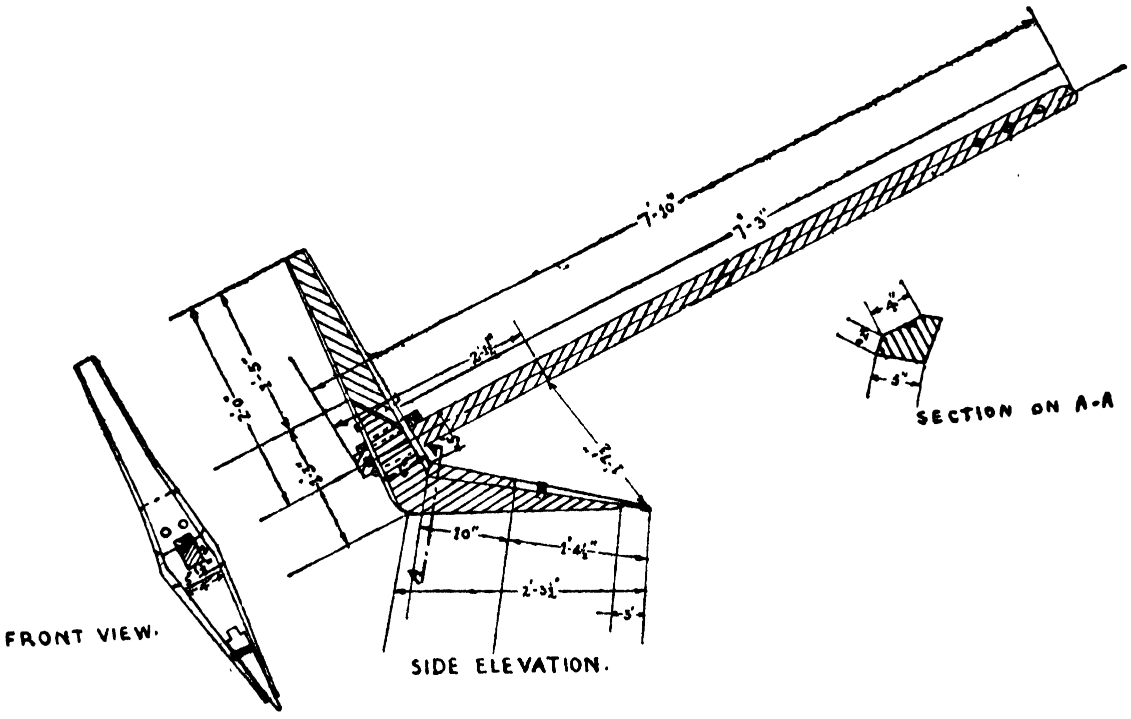


Fig. 33. Wooden plough, Berhampore (Orissa)

18·6° and the angles which the wedge makes with the body and beam are 120° and 49·9° respectively. The length of the wedge up to body is 17 in. and up to its intersection with the beam is 22 in. The length of the share is 9 in. and the weight of the plough is 17·2 lb.

(33) *Country plough, Sambalpur* (*Orissa*). The dimensional diagram is given in Fig. 32. The body and wedge are in one piece. The beam is fixed to the body at a distance of 8 in. from the inner bend and is of rectangular cross-section 2 in. × 2½ in., its length being 7 ft. 5 in. A separate handle is fixed to the body. The wedge is a pyramid of triangular cross-section with sides 13 in., 6½ in. and 6½ in. at maximum sections. The two edges are curved slightly. The length of the wedge up to the body is 20 in. and up to its intersection with the beam is 32 in. The face angle of the wedge is 40° and the angles which the wedge makes with the body and the beam are 140° and 30° respectively. The length of the share is 11 in. and the weight of the plough is 19·2 lb. The plough is used for puddling paddy fields. The average rainfall is as follows: January = 0·41 in., February = 0·79 in., March = 0·94 in., April = 0·65 in., May = 1·25 in., June = 10·92 in., July = 20·02 in., August = 19·19 in., September = 8·51 in., October = 2·00 in., November = 0·83 in., and December = 0·22 in.

(34) *Wooden plough, Berhampore* (*Orissa*). The dimensional diagram is given in Fig. 33. The body and wedge are made in one piece. The beam is fixed to the body at a distance of 1 in. from the inner bend and is of rectangular cross-section 2 in. × 3 in., its length being 7 ft. 10 in. A separate piece of wood is fixed to the body to serve as handle. The wedge is a solid of pentagonal cross-section with sides 5 in., 2 in., 4 in., 2 in. and 5 in. at maximum section and with the 4 in. side facing upwards. The length of the wedge up to body is 26½ in. and up to its intersection is 31 in. The face angle of the wedge is 17° and the angles which the wedge makes with the body and beam are 135° and 41·3° respectively. The length of the share is 16½ in. and the weight of the plough is 36·4 lb. The average rainfall is as follows: January = 0·35 in., February = 0·88 in., March = 1·07 in., April = 1·40 in., May = 5·51 in., June = 10·04 in., July = 10·85 in., August = 11·95 in., September = 10·12 in., October = 4·20 in., November = 0·62 in., and December = 0·12 in.

(35) *Orissa plough, Bhadrak*. Similar to Sambalpur in design.

(36) *Orissa plough, Angul.* Similar to Sambalpur plough in design.

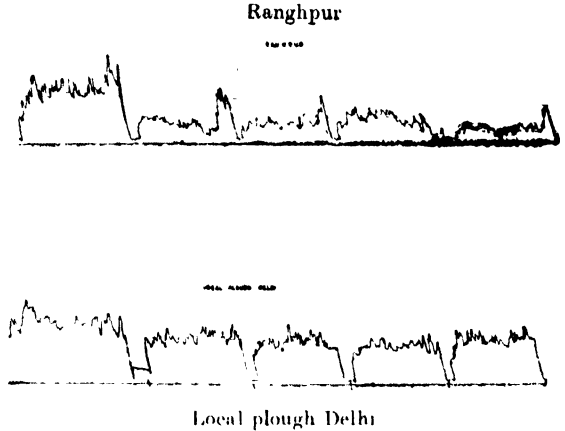
EXPERIMENT

With the object of making comparative study of the Indian ploughs and also to investigate the fundamental principles involved in their design, dynamometer experiments were conducted in January 1941 with 40 ploughs, collected from different parts of India, which are described above. The field used for this experiment was plot No. 3 Main Block Farm area, Imperial Agricultural Research Institute, and the soil is sandy loam. The plot was level and had been ploughed and left fallow for two months before this experiment. The data were collected as follows: Five furrows, each 100 ft. long, were opened in succession by each of the ploughs, the first one being an opening furrow while the remaining four furrows followed as normal ploughing. Same ploughman and the same pair of Sahiwal bullocks were used throughout the experiment. Charts showing the draw-bar-pull (D. B. P.) fluctuations throughout the length of the furrow were obtained for each furrow with the help of a self-recording dynamometer. The description of the dynamometer is given in Appendix I. The average draw-bar-pull (D. B. P.) for the different furrows was calculated by computing the area included in-between the curve and the base line by means of a planimeter and dividing this area by the length of base line and multiplying the quotient by dynamometer constant. Specimens of the D. B. P. curves obtained for two of the ploughs are given in Fig. 34. In addition to the draw-bar-pull, the depth and width of each furrow were recorded by taking measurements at three points selected at random in each furrow. The moisture content was also determined by taking soil samples from each furrow. The total width covered by five furrows and the time taken to open each furrow were also noted. The angle between the beam and the ground line was calculated by noting the length of the beam and the height of the free end of the beam above the ground line when the plough was in working position.

Table I summarizes in brief the results of this experiment. The different ploughs have been arranged in ascending order of draw-bar-pull.

DISCUSSIONS

From the examination of diagrams of all ploughs it can be seen that there is considerable difference


Ranghpur

Local plough Delhi

Fig. 34. Specimens of the D.B.P. curves

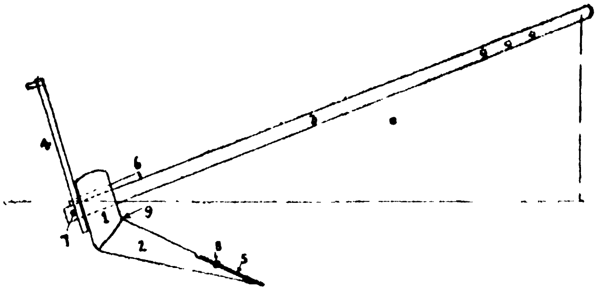


Fig. 35. Side elevation view of an Indian plough
1. Body, 2 Wedge, 3. Beam, 4. Handle, 5. Share or iron rod, 6. Cotter or small wedge, 7. Pin, 8. Ring to hold the share in position, 9. Inner bend
*These notations have been used throughout this paper

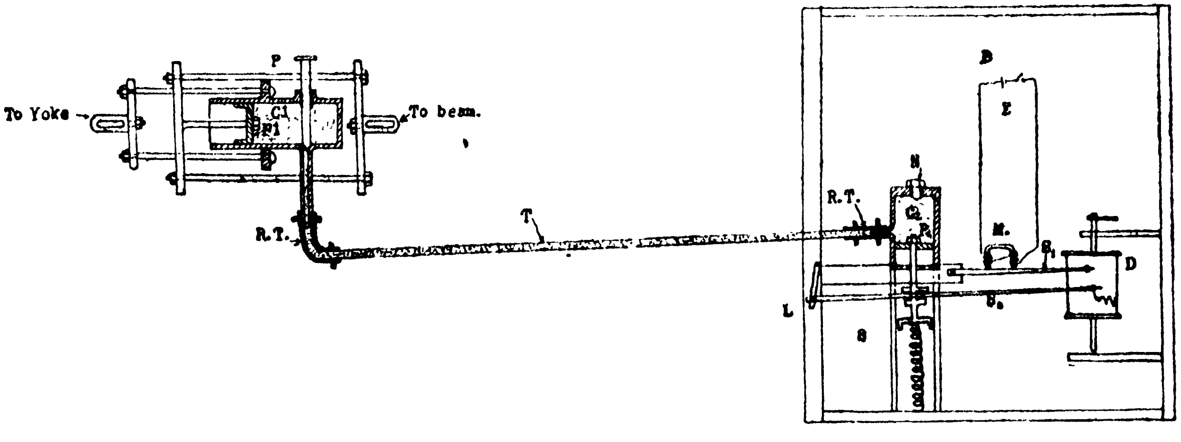


Fig. 36. The sectional view of the dynamometer

C1=Main cylinder
C2=Auxiliary cylinder
P=Pin to control the flow of oil from main to auxiliary cylinder
P1=Main piston
P2=Auxiliary piston
T=Metal tube
R.T.=Rubber tubes (special) for joining purpose
S=Spring
S1=Stylus No. 1
S2= ,, ,, 2
L=Lever
N=Nut to close the oil inlet of auxiliary cylinder
M=Electro magnet
B=Battery
D=Paper drum on which stylus No. 2 records the movements of the P2 which is proportional to the pressure on oil

TABLE I*

Summary of observational data

Name of the plough	Average moisture percentage	Average width of the furrow in inches	Average depth of the furrow in inches	Area of the cross section of furrow	Time taken in seconds to travel 100 ft. furrow	Plough angle, i.e. angle between beam and wedge	Angle which the beam makes with horizontal	Ploughing angle, i.e. inclination of wedge to the horizontal	Weight of the plough in lb.	Resistance per sq. inch based on first furrow	The length of the beam in ft. and in.	The length of the wedge up to body in inches	Draw-bar-pull for the first furrow in lb.	Average draw-bar-pull for the 4 successive furrows in lb	H. P. on the basis of first furrow	H. P on the basis of subsequent furrow
1 Country plough Kakori	8·92	7·00	3·83	13·40	31	30·00	..	..	25·88	2·55	9—3	..	35·68	27·9	0·22	0·17
2. Country plough Gorakhpore No. 1	9·5	8·2	5·5	22·55	27	40·00	..	..	18 2	1·59	9—4	16·0	35·9	40·9	0·25	0·29
3. Country plough Bareilly No. 1	10·36	6·66	4·00	13·37	29	33·05	23 6	9·45	24·00	4·40	8—9	..	58 6	62·6	0·37	0·40
4. Local plough Chotanagpur Purelia	8·36	9·83	6·00	30·47	28	48·60	20·4	28 20	25·10	2·16	7—10	20·0	65·9	46·0	0·43	0·30
5. Local plough Chotanagpur Ranchi	10·67	10·00	5·20	26·00	30	39·05	23·3	15 75	16 40	2·81	6—6	14·0	70·5	48·8	0·43	0·30
6. Orissa plough Udayagiri	8·59	10·33	6·00	30·99	23	49·90	20·4	29 5	17·20	2·65	7—5	17·0	82·3	55·4	0·65	0·44
7. Local plough Chotanagpur Daltanganj	8 78	10·83	6·00	32·50	25	39·80	22 9	16 9	30·20	2·62	8—7	..	85·1	84·5	0 62	0·62
8. Country plough Pusa Farm	9 17	10·20	6·50	33·15	25	44·90	24·9	30·0	34·34	2·66	8—1	13·0	88·2	60·7	0·63	0·43
9. Orissa plough Sambalpur	8·28	12·33	4·83	29·77	32	..	21·2	..	19·20	3·02	7—6	16·0	89 8	32·6	0·51	0·19
10. Wooden plough Tipperah	9·26	9·33	5·33	24·87	28	..	20·7	..	28 00	3 83	7—4	22·0	95·3	100·2	0·62	0·65
11. *Desi* plough Gorakhpore No. 2	9·25	8·66	7·00	30·30	31	45·00	20·0	25·00	22·00	3·58	9—2	12·0	108·6	102·5	0·64	0·60
12. Orissa plough Bhadrak	9·58	11·83	5·20	30·76	35	43·45	24·0	19·40	19·50	3·58	7—8	19 0	110·2	106·7	0·58	0·56
13. Wooden plough Gorakhpore	9·15	9·66	6·33	30·57	30	45·00	20·0	25·00	22·66	3·86	9—3	15·0	118·0	124·5	0·72	0·76
14. Orissa plough Angul	8 72	11·20	6·00	33 60	26	43·45	24·0	19·40	24 10	3·60	7—1	19·0	121·2	103·8	0·85	0·73
15. Local plough Chotanagpur	9·00	8·33	5 83	34·30	26	49·65	19·9	29·75	34·33	3·70	9—2	21·0	125·0	105·5	0 88	0·74
16. Country plough Rangpur	9·56	9·00	5 67	25·5	25	46·15	27·1	19·05	20 0	4·96	7—6	23·0	126 5	35·3	0 82	0·23
17. Country plough Bankura	9 81	12·00	6·33	37 98	27	41·85	23·05	18·8	31 0	3 36	8—5	19·5	127 7	147·1	0 86	0·99
18. Native Sind plough Mirkapur	8·51	9·00	6·67	30 0	32	46·81	30·0	16 81	35 4	4·43	9—4	20 0	133·0	95·0	0·76	0·57
19. *Desi* plough Gorakhpur No. 3	9·5	9·00	6·60	29·70	30	49·1	26·1	23 0	23·57	4·51	8—9	20·0	134·0	122·1	0·82	0·75
20. Wooden plough Berhampore	9·3	10·0	7·66	38·3	28	41·3	27·1	14 2	36·4	3·51	7—10	26·5	134 4	143·3	0·88	0·94
21. Kannar plough	9 11	12 33	6·66	60·05	36	48·1	22·9	25·2	37 9	2·40	9—5	..	144 0	160·7	0 75	0·84
22. Local plough Chotanagpur. Netarhat	9·12	12·0	5·33	45 98	26	48·35	21·7	26 6	41·8	3 25	9—7	26·5	130 7	76·4	1·06	0·54
23. Local plough Delhi	9 3	10·8	6·42	34·67	29	41 3	20·4	20 9	59·4	4·44	9—1	..	153·8	145·9	0·99	0·94
24. Country plough Patna	10·48	11·00	7·67	42·19	27	39·5	23·1	16·4	24 8	3·89	8—11	22·5	164 5	119·5	1·11	0·81
25. Country plough Aligarh	9·18	9·83	7·83	37·65	34	44·4	24·4	20 0	29·2	4·41	9—5	18·0	166 2	173·0	0·89	0·93
26. Country plough Jhansi	9·62	7·66	6·5	24·9	32	..	21·6	..	44·1	6·72	..	26 0	167 4	134·1	0·96	0·77
27. Country plough Oudh	9 98	7·83	7 00	27 4	29	..	23·6	..	17·0	6·10	7—11	..	167·3	135·2	1·05	0·85
28. Plough Dacca Farm	9·45	9·33	7·0	32 66	28	45·6	20·7	24 90	23 9	5·57	7—4	22·0	182·0	184·8	1·18	1·20
29. Native plough Sabour	9·09	11·5	7·83	45 0	30	45·5	20·5	25·1	44·1	4·62	9—5	28 0	208 0	220·9	1·27	1·35
30. Country plough Bareilly No. 2	9 09	8·66	7·16	31 0	42	45·1	22·0	23 1	25·1	7·30	9—1	22·5	226·2	261·24	0 98	1·13
31. Country plough N.-W. F. P.	8 8	11·2	7·0	39·2	40	.	21·4	..	47·8	6 98	9—3	16·0	273 5	245·1	1·25	1·12
32. Orissa plough Potangi	8 61	8 0	8 33	33 32	30	26·35	20·7	5·65	19·2	8·80	7—8	18 0	293 2	191·2	0 92	0·60
33. Local plough Karnal	8·4	12·0	8 2	49 2	29	44·5	21·5	23 0	51 6	6·00	10—11	22 0	295·9	296·6	1·86	1·87
34. Victory plough	8·06	12·33	5·83	71·88	40	..	20·4	..	80 0	4 19	12—0	..	299·0	360·6	1·86	1·64
35. Country plough Baroda	8·34	11·5	8 0	46·0	33	37·60	19·6	18·06	50 7	6·63	11—4	23·0	305·6	261·57	1·69	1·45
36. Sarkar plough Sind	9·12	12·33	8 00	61 00	34	43·0	22·5	20·45	33·3	5·00	11—5	..	305·0	236·1	1·64	1·27
37. Country plough Coimbatore	8·64	11·0	9·0	49 5	35	40·96	22·0	18 96	37·4	6·82	11—7	29·0	228·0	328·0	1·76	1·71
38. Country plough Dohad	7 66	9·33	9·33	43·5	24	43 00	21·4	21 53	28·7	8·28	9 4	18·0	260·0	350·0	2·73	2·65
39. Heavy country plough Bellary	9·11	9·66	9·00	43·3	46	42·2	..	..	81·5	8·90	9—2	32·0	387 5	390·0	1·54	1·55
40. Country plough Indore	8·28	9·63	10·66	51·5	43	42 5	21·3	21 2	56 9	8·08	10—4	20 0	416 0	403·5	1·76	1·71

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* The help rendered by Mr A K. Kaul, Engineering Assistant. Imperial Agricultural Research Institute, in maintaining the dynamometer is gratefully acknowledged.

between the ploughs in their construction. The following are the main differences:

1. In some of the ploughs the body and wedge are made in two parts and have been assembled together, while in others they have been made in a single piece. In the former case if the wedge is damaged it can be replaced, and at the time of constructing the body and wedge very little wood is wasted. The angle between the body and wedge can easily be altered whenever required, as the tightening of these parts is done with the help of the cotters or pegs, while the angle between the body and wedge in the other type cannot be altered. Any wood can be used subject to the strength of the material to withstand the forces acting on the plough due to the soil. In other types a wood which is quite hard and has very little wear and tear like acacia should be used. In the first type, however, the wedge is likely to get loosened soon and cause damage to the body as the tightening is done by cotters.

2. In some ploughs the beam is fixed to the body at a farther distance from the bend between the body and wedge, while in others it is very near. The advantage in the former case is that when the plough is working in a field full of weeds, the weeds do not cause any undue increase in draught by sticking to the plough and blocking the passage of the plough. Besides this, the depth of ploughing will be greater than in the latter case provided the length of wedge and the plough angle are same in both cases.

3. The wedges are broad and short in some cases while in others they are narrow and long. The ploughs with broad and short wedges are used in soils where moisture is high, i.e. generally for puddling, in which case the cutting force is less. If the ploughs with long and narrow wedges are used in soils with high moisture content, they will penetrate to a greater depth due to which the draught will be more. While cutting with narrow wedges the sides of the furrows will be intact (i.e. the disturbance of the soil near the side of furrows is very little) and produce a side pressure on the wedge of plough which will cause an increase in the frictional resistance. Therefore, the total resistance per unit area of cross-section of the furrow opened is greater in the case of ploughs with narrow wedges than that of the ploughs with short and broad wedges. The disadvantage of ploughs with broad and short wedges is that they plough the land to a lesser depth than the other case.

4. In certain ploughs the wedges are solid pyramids with triangular cross-section while in others they are of different shapes, some conical, some trapezoidal frustums and others solid cones having a cross-section like segment of an ellipse (cut by a line parallel to its minor axis). In the former type the vertex of cross-section faces downwards.

Examining the ploughs from their construction point of view it will be seen that a classification on constructional basis can mainly be done from the point of their wedges on which the working capacity of a plough depends. Applying this criterion the following classification has been made:

(1) *Ploughs with broad and short wedges with triangular cross-sections.* Sambalpur, Angul, Bhadrak and Bankura ploughs will fall in this class. They are similar not only in their wedges but in the attachment of their beams to the bodies and in other constructional points of view. The Bankura plough has a slightly longer and narrower wedge than the others. The body and the wedge are made in one piece.

(2) *Ploughs with broad and long wedges with triangular cross-section.* Native plough Sabour falls in this class. The body and the wedge are made in one piece.

(3) *Ploughs with broad trapezoidal frustum wedges.* Local plough Chotanagpur Netarhat and local plough Chotanagpur come in this class. They have no bodies. Sarkar plough Sind and North-West Forntier Province plough with their trapezoidal wedges can also be placed in this class. But the beam of the North-West Frontier Province plough is curved and the coulters of Sarker and North-West Frontier Province ploughs are flat iron plates. The body and wedge are made in one piece

(4) *Ploughs with long wedges of medium breadth with triangular cross-section.* Bellary, Coimbatore and Berhampore ploughs will come in this class. In the case of Bellary ploughs the cross-section of the wedge is triangle. The vertices of the cross-section of the wedge of Coimbatore plough are slightly flattened while that of Berhampore plough are flattened in such a way that the section has become pentagon. Jhansi plough also can be placed in this class, but one of the vertices of the cross-section of the wedge has been rounded and this curved face faces downwards. The beam of the Jhansi plough is curved. The body and wedge are made in one piece in this also.

(5) *Ploughs with specially designed wedges.* *Desi* plough Delhi and Local plough Karnal will come in this class. The wedge of Delhi plough is partly iron and partly wood. The iron part is a flat plate of triangular section $\frac{3}{8}$ in. thick. The wooden part and the body are made in single piece. Similarly in the case of Local plough Karnal, the wedge is of two cross-sectional dimensions. Part of the wedge is a pyramid of segmental cross-section and the remaining part is a solid with sectoral cross-section as shown in diagrams.

(6) *Ploughs with wedges of medium length and width.* There are two sub-types in this class:

(a) *Ploughs with body and wedge made in one piece*--Patna, *Desi* Gorakhpur No. 3, Wooden Gorakhpur, Country Pusa Farm, Chotanagpur Purelia, Ranchi, Dacca Farm, Rangpur and Udayagiri ploughs will come in this class. In the case of Dacca and Rangpur ploughs the edges of their wedges are slightly rounded.

(b) *Ploughs with body and wedge made in two pieces* *Desi* Gorakhpur No. 1, *Desi* Gorakhpur No. 2 and Aligarh ploughs will come in this class.

(7) *Ploughs with small and thin wedges.* Bareilly No. 1 and Kakori ploughs will come in this class. Their wedges are of insignificant size. They are probably used as harrows.

(8) *Ploughs with narrow and long wedges.* Country Dohad, Indore, Bareilly No. 2 and Baroda ploughs will come in this class. In Baroda plough the wedge is conical and different from that of others. The Potangi plough also can be placed in this class but the beam and handle are curved. There is no body and the wedge is a solid cone and resembles the primitive type

(9) *Ploughs with bodies and shares made of iron.* Kannar plough will come in this class. The body and share are specially designed. The beam is wooden and the plough is a modified form of Victory plough.

Now coming to the classification on the basis of crops and the conditions of the soil at the time of ploughing, it can be seen that the following classification can be made.

(1) *Ploughs which are intended only for wet land paddy fields.* Sambalpur, Angul, Bhadrak, Bankura, Local plough Chotanagpur, L. P. Chotanagpur Netarhat, with their broad and short wedges, come in this class. In the case of wet land paddy fields, puddling is the main operation to prepare the soil for transplantation and this can be done under waterlogging conditions. So these ploughs are more useful than the ploughs with the narrow and long wedges. Sabour plough with slightly modified wedge can be placed in this class.

(2) *Ploughs which are intended for paddy fields and dry lands under various other crops.* Dacca Farm, Rangpur, Tipperah, Karnal, Sarkar Sind, Bellary, Coimbarote and *Desi*-Gorakhpur ploughs will come in this class. These ploughs are used for puddling paddy lands and also for ploughing the fields for other crops. Ploughing is done when the moisture content of the soil is sufficient to make it ploughable. If the moisture due to rain is insufficient, ploughing is done after irrigation. Karnal, Bellary, Coimbatore and Gorakhpur ploughs are used for preparing land for sugarcane also.

(3) *Ploughs which are intended for dry land crops only.* The remaining ploughs with long and narrow or medium wedges will come in this class. Some of these ploughs are used in rainfed areas only while others are used in both rainfed and irrigated areas. In these cases also ploughing is done when the moisture content of the soil is sufficient to make the soil ploughable.

The experimental results and the charts showing the draw-bar-pull indicate that the draw-bar-pull in the case of first furrow is more than in the case of subsequent furrows in many cases. But as it was very difficult to distinguish whether the subsequent furrows were made as in the case of normal ploughing, the investigations were confined mainly to data from the first furrows. However, the average draw-bar-pull for the successive furrows is also given in Table 1 for the purpose of comparison.

Taking the ploughs of the different groups mentioned above on crop basis, the values of width and depth of the furrows, the D. B. P. weight, of ploughs, resistance per unit area of cross-section, horse-power (H.P.) and time enable us to see which plough can be regarded as the best in the different groups.

In the case of Bankura plough the H. P. and the resistance per unit area of cross-section of the furrow are comparatively minimum, while the cross-section and the depth of the furrow are maximum. The wedge of this plough is more pointed than that of the others in this Group and this probably may be the cause for maximum depth. Besides this, the weight of the plough is quite sufficient to make it strong so that the plough can

GROUP I

Name of plough	Furrow		Weight in lb.	Time to open 100 ft. furrow in sec.	D. B. P. in lb.	Resistance	H. P.
	Width	Depth					
Sambalpur	12·33	4·83	19·2	32	89·8	3·02	0·51
Angul	11·20	6·00	24·1	26	121·0	3·60	0·85
Bhadrak	11·83	5·20	19·5	35	110·0	3·56	0·58
Bankura	12·00	6·33	31·0	27	127·7	3·36	0·86
Local Plough Chotanagpur	8·33	5·83	34·3	27	125·0	3·70	0·88
L. P. Chotanagpur Netarhat	12·00	5·33	41·8	26	150·7	3·25	1·06
Sabour with modified wedge	Not tried	Not tried	Not tried	Not tried	Not tried	Not tried	Not tried

GROUP II

Name of plough	Furrow		Weight in lb	Time in sec	D. B. P	Resistance	H. P.
	Width	Depth					
Rangpur	9·00	5·67	20·0	25	126·5	4·96	0·82
Dacca Farm	9·33	7·00	23·9	28	182·0	5·57	1·18
Tipperah	9·33	5·33	28·0	28	95·3	3·83	0·62
Desi Gorakhpur 3	9·00	6·60	23·6	30	134·0	4·51	0·82
Karnal	12·00	8·20	51·6	29	295·9	6·00	1·86
Sarkar Sind	12·00	8·00	33·3	34	305·0	5·00	1·64
Coimbatore	11·00	9·00	37·4	35	338·0	6·82	1·76
Bellary	9·66	9·00	81·5	46	387·5	8·90	1·54

be used for general ploughing operations in fields with proper moisture content. Hence the design of the wedge and construction of Bankura plough appears to be the best of this Group.

Group II can be divided into two sub-groups on depth basis. Rangpur, Dacca Farm, *Desi* Gorakhpur and Tipperah ploughs will come under first sub-group with depths between 5·33 to 7 in. Karnal. Sarkar Sind, Coimbatore and Bellary ploughs will come in the second sub-group with depths between 8 to 9 in. In the first sub-group, *Desi* plough Gorakhpur No. 3 can be considered to be the best. In the second sub-group the Sarkar Sind appears to be the best, but it is used in irrigated tracts only. Therefore, Karnal plough which is used under varying conditions, can be considered as the best design of this sub-group.

GROUP III

	Name of plough	Furrow		Weight in lb.	Time in sec.	D. B. P.	Resistance	H. P.
		Width	Depth					
I	1. Country plough Gorakhpur No. I.	8·2	5·5	18·2	27	35·9	1·59	0·25
	2. Local plough Chotanagpur, Ranchi	10·00	5·2	16·4	30	70·5	2·81	0·43
II	3. Chotanagpur Purelia	9·83	6·0	25·1	28	65·9	2·16	0·43
	4. Orissa plough, Udayagiri	10·33	6·0	17·2	23	82·3	2·65	0·65
	5. L. P. Chotanagpur, Daltonganj	10·83	6 0	30·2	25	85·1	2·62	0·62
III	6. Country Pusa Farm	10·20	6·5	34·3	25	88·2	2·66	0·63
	7. Wooden Gorakhpur	9·66	6·3	22·6	30	118·0	3·86	0·72
	8. Native Sind .	9·00	6·7	35·4	32	133·0	4·43	0·76
	9. Local plough Delhi	10·80	6·4	59·4	29	153·8	4·44	0·99
	10. Jhansi . .	7·66	6·5	44·1	32	167·4	6·72	0·77
IV	11. *Desi* Gorakhpur	8·66	7·0	22·0	31	108·6	3·58	0·64
	12. Country Oudh	7·83	7·0	17·0	29	167·3	6·10	1·01
	13. Country N.-W. F. P.	11·00	7·0	47·8	40	273·5	6·98	1·25
	14. Country Bareilly 2	8·66	7·2	25·1	42	226·2	7·30	0·98
V	15. Wooden Berhampore	10·00	7·7	36·4	28	134·4	3·51	0·88
	16. Country Patna	11·00	7·7	24·8	27	164·5	3·89	1·11
	17. Country Aligarh	9·83	7·8	29·2	34	166·2	4·41	0·89
	18. Native Sabour	11·50	7·8	44·1	30	208·0	4·62	1·27
VI	19. Country Baroda	11·50	8·0	50·7	33	305·6	6·63	1·69
	20. Orissa Potangi	8·00	8·3	19·2	30	293·2	8 80	0·92
	21. Country Dohad	9·33	9·3	28 7	24	360·0	8·28	2·73
	22. Country Indore	9·66	10·7	56·9	43	416·0	8·08	1·76

Group III can be divided into a number of sub-groups from the depth point of view as indicated in the above table. In the case of sub-group I, from H. P. and resistance point, Country plough Gorakhpur No. 1 seems to be better than the other one. In sub-group II, Chotanagpur Purelia appears to be the best of the lot. The weight is also quite sufficient to make it strong. In sub-group III, Country plough Pusa appears to be superior to any of the other ploughs. In sub-group IV, *Desi* plough Gorakhpur No. 2 requires much less D. B. P. and H. P. than any of the others. In sub-group V, Wooden plough Berhampore can be considered as the best. In sub-group VI, it will be seen that Country plough Baroda requires very strong bullocks while Potangi can be worked with average bullocks. In the above cases the ploughs which are considered to be the best can also be worked with average bullocks. Between the ploughs of Dohad and Indore, the design of Indore appears to be better.

SUMMARY

Ploughs collected from different parts of India have been examined from constructional, crop, draw-bar-pull depth of ploughing, resistance per unit area of cross-section of furrows and horse-power (H. P.) points of view, and attempts have been made to classify them on these basis. The draw-bar-pull charts, the depth and width of furrows, the time taken to open 100 ft. furrow were obtained by working the ploughs in the same field with the same pair of bullocks and ploughman and hence the deductions drawn from this experiment are purely comparative. The resistance and H. P. were calculated from D. B. P. depth and width of furrows and time.

In order to have a more definite classification the experiment should be repeated in different soils and comparison should be made on the above basis.

ACKNOWLEDGEMENTS

This work was taken up on the suggestion of Rao Bahadur Dr B. Viswanath. My sincere thanks are due to him and to Messrs C. H. Parr, P. V. Krishan Iyer and Mason Vaugh for helping me in writing the manuscript and for the valuable and helpful contributions by them. My thanks are due to the Directors of Agriculture of the different provinces for supplying the information regarding conditions under which the ploughs are used in the respective places.

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AEPPNDIX 1

DESCRIPTION OF THE DYNAMOMETER

A sketch of the dynamometer used for ploughing experiments is given in Fig. 36. It will be seen that it consists of two main parts, viz.

(i) A hydraulic link composed of a well-fitting main piston and a cylinder, connected by means of a metallic tube to an auxiliary cylinder fitted with a piston kept in a position by a spring S. The intervening space between the two pistons is completely filled with oil.

(ii) A self-recording arrangement which consists of a paper roll mounted on two spindles (not shown on diagram), and a drum provided with a mechanism for moving the paper at any desired speed.

One end of the hydraulic link is connected to the yoke and the other to the beam. The pull exerted by the bull is transmitted to the oil in the auxiliary cylinder by the transference of oil from the main cylinder through the connecting tube which causes the auxiliary piston to move. The movement of this piston is recorded on a special paper roll by means of a stylus S_1 connected to the auxiliary piston with a lever. When the plough is in continuous operation, the drum is rotated and the stylus S_1 leaves a continuous mark on the paper. In order to obtain a legible impression on the paper the pressure exerted on the paper by stylus should be adjusted by the screw provided for this purpose. Another stylus S_2 operated electrically by a dry cell can be used to mark points on the paper at any desired intervals. This will enable us to calculate the speed at which the plough is being worked at any interval (provided the paper and plough are moving at a definite speed).

Knowing the length of the ordinate of the curve above the base line at any instant, the D. B. P. at that instant can be calculated by multiplying it with the compressive value of the spring which is usually represented as so many pounds per inch of compression.

REVIEW

Annual Review of Biochemistry and Allied Research in India, Vol. XIII for 1942

(Society of Biological Chemists, India, Bangalore, Rs. 3 or 6s.)

INVESTIGATIONS in Biochemistry and allied subjects during 1942, are reviewed under 11 sections and cover varied fields of research. Each of these reviews draws attention to the increased volume of work. The important contributions made in the field of enzymes relate to the nature of the proteolytic systems in the whole blood, amylase inhibition by vitamin C, phosphates in seeds and the isolation of an enzyme from *Withamia Coagulanus*, an easily available substance in the market, for the preparation of rennet. Mention is made of the investigations which showed that phosphates content of milled rice is two-thirds that of hand-pound rice. It is also suggested that milling standards for rice can be established on the phosphates content of rice samples.

Under vitamins about 400 papers dealing with vitamin A, B, C, riboflavine and nicotinic acid are reviewed. Reference is made to the interesting experiments which showed that parboiled rice contained on the average four times as much vitamin B as washed raw rice and that wheat and millets generally contain their vitamin in the free state while pulses contain varying amounts of combined vitamins.

Widespread famine in different parts of the country raises the question of combating vitamin deficiency diseases and this problem has become more acute due to the scarcity of the imported vitamin concentrates due to war conditions. Work done in this direction is reviewed under the section of General Nutrition. It was found that Bengal gram contained 6 to 20 mg. of vitamin C per 100 gm. and that this vitamin is rapidly formed during germination reaching a maximum in 30 to 48 hours after which it remains stable for 3 to 4 days. It was shown that dehydrated foodstuffs are too low in vitamin C to be of practical importance and that of all the dehydrated fruits *amla* (*Phyllanthum emblicalin*) is unique in the sense that potent dry powder can be prepared having a potency of about 25 to 30 mg./gm. of vitamin C. The suggestions made for improving the present unsatisfactory state of food situation in India, to mention a few, are the manufacture of shark liver oil, the production of yeast and yeast extracts in India as substitutes for marmite and imported yeast products, the diversion of part of land at present used for money crops to food crops, the prohibition of polishing of rice and the harnessing of scientific methods in agriculture, animal husbandry and fisheries.

In the domain of human physiology the work reviewed relates among other subjects to the age estimation, blood chemistry, blood groups, health investigations, circulatory, digestive, reproductive and respiratory systems.

In the field of animal nutrition reference is made to the suggestion that in crop planning adequate attention should be paid to the needs of the cattle especially the dairy cow. The possibilites of growing giant star grass in India for fodder supply and erosion control are indicated. Investigations over the variations in the composition of berseem with the state of growth, the effect of maturity of some cereal plants, the carotene content of plant materials with special reference to hay making and storage,. are also reviewed. Mention is made of the work on the applicability of the freezing point test for detecting the adulteration of cow's and buffalo's milk and methods of preparing cheese of good quality.

The subject of human pathology continued to receive attention. Researches were carried out on dysentery, cholera, digestive system, endocrine glands, kala-azar, leprosy, plague, syphilis, typhus and several other diseases.

In plant physiology the reviews relate to nutrition, photosynthesis, chlorophyll, effect of radiation, reproduction, hormones, disposal of waste products and to ecology of diseases.

In the subject of chemistry of plant products investigations were carried on essential oils, fixed oils, sterols and lactones, plant colouring matters, alkaloids and glucosides, and the HCN content of giant star grasses.

Growing interest is evinced in the manifold problems presented by soils. Work reviewed relates to soil survey and soil classification, soil colloids and physico-chemical properties, movement of moisture and salts, soil swelling and shrinkage, soil erosion, soil micro-organisms, nitrogen fixation in soils, and manures and fertilizers.

An important contribution reviewed under soil survey and classification is the preparation of the soil map of India which presents a general idea of evolutionary status of the Indian soils under varied geological and climatic conditions. Reference is made to the investigations on the effect of fertilizer treatments for a number of years on the permanent manurial plots at Pusa on the nature of soil micro-organisms and their activity and to the observed correlation between the crop yields and microbial activity. The work on cotton which showed that cotton seeds coated with dry ammonium sulphate before sowing gave better yields than when the manure was applied as top dressing or during drilling is also reviewed. Attention is drawn to the investigation on the availability of nitrogoen in soils with application of F. Y. M. under different conditions of moisture and C : N ratios on black cotton soil under continued cane growing, which showed that soils with wide C : N ratio did not respond to F. Y. M. as the mineralization of F. Y. M. in such soils was poor.

While this review contains a faithful record of the activities of Indian workers and as such, much valuable information can be obtained from it, its utility can further be enhanced by the reviewers making their reviews more complete by consulting the reports of the various Provincial agricultural departments and University magazines as well as the reports of the irrigation research laboratories and those of the private Research Institutions. Work published in Indian Journal of Pharmacy is not reviewed under either pharmacy or chemistry or plant products, work published in Journal of Malarial Institute of India is not reviewed in human pathology under malaria and that in Madras Agricultural Journal, Poona Agricultural College Magazine are not referred in soil and fertilizers, to mention a few instances of obvious omissions. The contribution on the geological evolution of Gujerat and study of the dietary and nutritional status, published in the Journal of the Gujerat Research Society missed the attention of the reviewers. Further, in some cases investigation on the same subject is reviewed by several reviewers under different heads while some investigations like those on fermentation are not reviewed in any of the branches. The work on nitrogen fixation by algae, review of nitrogen fixation, work on haemopoietic systems, uropoietic systems and the investigations on the relation between interval of cutting and yield and chemical composition of perennial grasses are reviewed in more than one place. A slight change in the divisions to be reviewed and a little editorial touching may eliminate these defects. It is fervently hoped that the reviews may be published at least within six months of the close of the year under review so as to make it more useful to the workers in the different branches of Biochemistry and allied subjects.- S.V.D.

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